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Benefits of Maintaining a Chlorine Residual in Water Supply Systems

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The protection afforded the water consumer by the maintenance of a chlorine residual in water distribution systems was evaluated in laboratory holding tanks and reservoirs and existing municipal water distribution systems. In the laboratory studies, tap water, adjusted to the appropriate pH, temperature, and chlorine residual, was challenged with with varying levels of autoclaved sewage seeded with Shigella, Salmonella coliforms, poliovirus 1, and f2 bacterial virus. Comparative survivals of these microorganisms were evaluated over two hour periods. As expected microbial inactivation was increased by lower pH, higher temperature, higher initial chlorine concentration, and lower sewage concentration. An initial free chlorine concentration was more effective than an equivalent initial combined chlorine residual. The maintenance of a free chlorine residual was found to be the single most effective measure for maintaining a low plate count in the distribution system. More than 6000 plate count isolates were studied and classified into functional groups based on seven biochemical characteristics.

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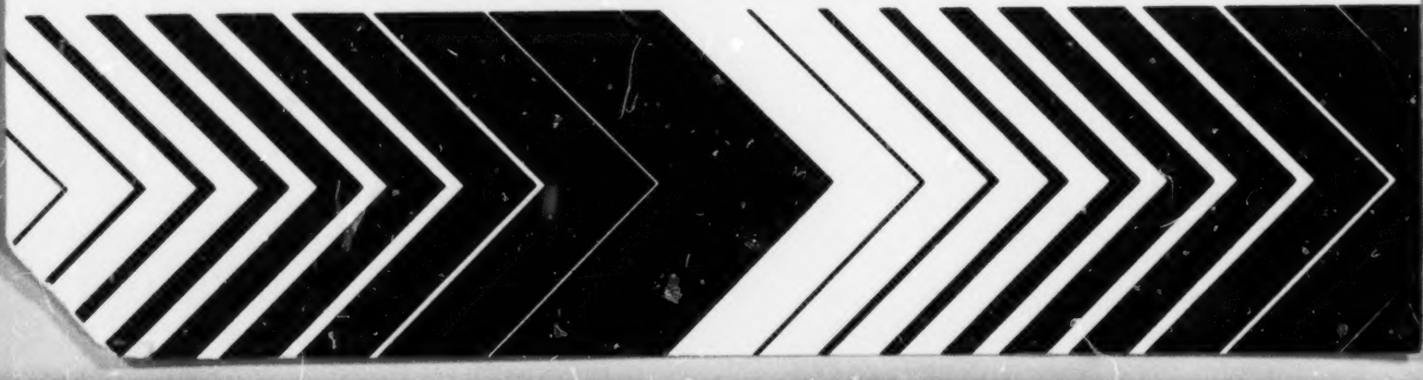

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BENEFITS OF MAINTAINING A CHLORINE RESIDUAL IN WATER SUPPLY SYSTEMS

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report evaluates the effectiveness of chlorine in water distribution systems in inactivating microorganisms introduced by post-treatment contamination. The relationship of chlorine residual, turbidity, pH, and temperature to levels of bacteria found on plate count agar, and biochemical characteristics of these bacteria are presented for samples from the Baltimore, Maryland and Frederick, Maryland water distribution systems.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

ABSTRACT

The protection afforded the water consumer by the maintenance of a chlorine residual in water distribution systems was evaluated in laboratory holding tanks and reservoirs and existing municipal water distribution systems. In the laboratory studies, tap water, adjusted to the appropriate pH, temperature and chlorine residual, was challenged with varying levels of autoclaved sewage seeded with *Shigella sonnei, Salmonella typhimurium,* coliform organisms (IMVIC ++--), poliovirus 1, and f2 bacterial virus. Comparative survivals of these microorganisms were evaluated over two hour periods. As expected, microbial inactivation was increased by lower pH, higher temperature, higher initial chlorine concentration, and lower sewage concentration. An initial free chlorine residual was more effective than an equivalent initial combined chlorine residual. Generally, *S. sonnei, S. typhimurium* and coliform organisms were inactivated at the same rate but poliovirus 1 was more resistant and f2 was the most resistant. At pH 8, with an initial free chlorine residual of 0.7 mg/liter, and sewage added to levels of up to 1% by volume, 3 logs or greater bacterial inactivation was obtained within 60 minutes. Viral inactivation under these conditions was less than 2 logs. In reservoir studies, where the residual chlorine is replenished by inflow of fresh uncontaminated chlorinated tap water, greater inactivation was observed at the higher sewage concentration levels tested. 986 samples were collected from the Baltimore (850) and Frederick (136) water distribution systems and assayed for coliforms. Standard plate counts, 35°C plate at 4 days (PC 4) and 20°C plate at 9 days (PC 9) were made and turbidity, pH, temperature and chlorine residual measurements were taken. Coliforms were rarely found in the Baltimore system and infrequently recovered from the Frederick system. Significant positive correlation (≥ 95% level) were observed in both water systems for PC 4 and PC 9 versus turbidity and temperature. Significant negative correlation (≥ 95% level) were observed for PC 4 and PC 9 versus chlorine residual. The maintenance of a free chlorine residual was found to be the single most effective measure for maintaining a low plate count in the distribution system. More than 6000 isolates from the 20°C and 35°C plate counts were further studied and classified into 43 functional groups based on seven biochemical characteristics. Eight groups made up 76% of the observed microorganisms. Although the frequency of isolation and level of these groups was variable from sample to sample and station to station, only few groups of microorganisms predominated at each of the incubation temperatures and in each of the distribution systems.

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SECTION 1

INTRODUCTION

The construction of piped water supplies for communities across the United States was a phenomenal achievement of the 20th century. Compared to Europe the waterworks in the United States got a slow start, records showing a total of only 243 works by 1875. Only two of these 243 waterworks were slow sand filtration plants, an almost universal practice abroad for surface water sources. In the U.S. early systems were untreated upland springs, impoundments and a large number of well supplies. The number of systems by 1895 increased by one order of magnitude to about 3000. Records were not precise and the rate of construction was quite rapid at 1000 per year. The slow sand filter performed well on the less turbid surface sources generally found in the northeastern cities. For the big rivers such as the Ohio and Mississippi the filters could not function without pretreatment. After initial failure the mechanical or rapid sand filtration plant was made reliable primarily by improved coagulation and backwashing technology. By the turn of the century only one third of the total population was served by public water systems of which less than 2 million persons consumed filtered surface water. By then, 80 percent were of the rapid sand type. Public water quality was not good and the liability for disease contracted from these systems was frequent and both municipal and private corporations were held responsible. Regulation regarding water quality was somewhat improved by insisting on protected watersheds and ground water sources, smaller cities and towns had outgrown their supplies and often went to the nearest river or lake without satisfactory treatment. Waterborne disease conditions were such that the USPHS began active interest in typhoid fever spread from the great interstate rivers. Their findings were incorporated into standards and with the implementation by the states waterborne diseases began to abate. It was not however, until the introduction of disinfection with chlorine in 1908, the practice of which spread very rapidly through all the states on order of boards of health, that public water systems were no longer important in the spread of typhoid. It was estimated that by 1924, 37,000,000 persons were protected by chlorination in some 3000 cities and towns. Control of early chlorination practice was based on the dose of chlorine applied. Recommendations for dosage levels for filtered water were 0.6 - 1.2 mg/liter (Folwell, 1917), 0.20 to 0.25 mg/liter (Turneaure and Russell, 1924), and 0.24 to 0.96 mg/liter (Waterman, 1934). In 1917, Folwell stated that "the only safe rule is to test the germicidal effect of different doses on the water in question". Wolman and Enslow (1919) advocated dosage based on "chlorine demand" of water determined at 5 minutes at 20°C. The dose was "chlorine demand" plus 0.2 mg/liter. The maintenance of a chlorine residual throughout a water distribution system was specifically not recommended, because of alleged problems with unpleasant taste and odor. When excess prechlorination was used for algae destruction (because of a polluted water source) very high levels of chlorine were required and dechlorination was advocated before release of the water to the distribution system. The practice of heavy prechlorination was considered wasteful and was not widely practiced in the U.S. Double or multiple chlorination pre and post filtration was quite common in the early 1930's, however, unpleasant tastes and odors were of concern since dosage rarely if ever exceeded breakpoint.

In an effort to solve chloro-taste problems disinfection with a mixture of chlorine and ammonia sometimes was successful mainly because the dosage of chlorine required for demand plus 0.2 ppm residual for 10 minutes was very low. As advocates of the method were quick to point out, the chlorine residual resulting after the chlorammoniation process was also more stable. Since the chlorine residual was stable, did not produce complaints of taste and odor, and reduced bacterial aftergrowth that occured in the distribution system (Baylis, 1935), the process became widely acceptable and the purposeful maintenance of a chlorine residual throughout all or part of the distribution system was first initiated. The 1941 American Water Works Association Water Quality and Treatment manual provides the following statements on the chlorine-ammonia treatment:

> As a means of eliminating tastes and odors caused by the condition of the untreated supply water, the effectiveness of the process is quite limited.
>
> As a means of preventing the formation of tastes and odors in the stagnant sections of the distributing systems, it is almost universally successful.
>
> The process proves to be of real assistance in the reduction of "dead-end" red water complaints.
>
> For prolonged sterilization, it is much more practical than chlorine alone.

The manual goes on to say 'Today the ammonia-chlorine is widely used and its limitations are as well understood as its merits".

It is interesting to note that the chlorine-ammonia process was in use for some twenty years before the elucidation of the breakpoint phenomenon of the chlorination of water, which occurred in the late 1930's. With this discovery, came the realization that free forms of chlorine are more rapid and effective as disinfectants. Chlorination to a free residual was found to be an effective means of controlling coliform organisms in newly laid water mains. The 1950 American Water Works Association Water Quality and Treatment Manual shows the gain in acceptance of free residual chlorination. "In very recent years, the functional advantage of treatment employing amounts of chlorine greater than those formerly considered adequate has become clearly appreciated. The wider adoption of treatment utilizing greater chlorine additions may be expected to develop in the future, inasmuch as high-rate chlorination provides a means of achieving a higher standard of bacterial quality and of improving plant practice, including the elimination of certain types of tastes and odors". The manual goes on to give definitions of combined residual chlorination that are still applicable today. "Combined residual chlorination is defined as the application of chlorine to water to produce, with the natural or added ammonia, a combined available chlorine residual, and to maintain that residual through part or all of a water treatment plant or distribution system. Free residual chlorination is defined as the application of chlorine to water to produce directly, or through the destruction of ammonia, a free available chlorine residual, and to maintain that residual through part or all of a water treatment plant or distribution system". By 1950, approximately 500 water treatment plants in the U.S. were practicing free residual chlorination.

The value of residual chlorine in the distribution system has received considerable attention. While the military had no policy concerning residual chlorine, it was recommended by all services that chlorination be accomplished to levels of free residuals for specified times which under conditions of natural waters was equivalent to breakpoint. At the request of the Army, the National Academy of Sciences National Research Council (NAS-NRC) prepared a statement (1953) which stated in part:

> "Residual chlorine in the concentrations routinely employed in water utility practice will not ordinarily disinfect any sizeable amounts of contaminatory material entering the system, though this will depend on the amount of dilution occurring at the point of contamination, on the type and concentration of residual chlorine and on the time-of-flow interval between the point of contamination and the nearest consumer .... It is the opinion of the NAS-NRC that the establishment of a *universal* standard for maintaining residual chlorine in the water in distribution systems is not desirable .... The NAS-NRC does not consider maintenance of a residual a satisfactory substitute for good design, construction and supervision of a water distribution system, nor does it feel that the presence of a residual in the system constitutes a guarantee of water potability".

Formal scientific discussion on the value and limitation of chlorine residuals in distribution systems have not taken place since 1958, although since the war there has been an increase in the number of towns and cities that maintain residuals in their distribution system. At that time, it was concluded that agreement with the NAS-NRC statement was not universal and that one well documented value of the chlorine residual was the reduction of coliform organisms in the delivered water. However, at the same time it was believed that normal residuals could not overcome the infrequent but devastating external gross contamination by cross-connections and back siphonage defects. The loss of residual would serve as a valuable tracer and warning device. The observed lowering of coliform by chlorine was believed to be merely a control of after-growth, the health significance of which was debatable. Therefore, it was no surprise that controversy on system residuals still exists. The National Community Water Supply Survey (CWSS) (McCabe *et al.*, 1970) conducted jointly by the PHS and state health departments contained bacteriological data from distribution systems for 954 of the 969 systems surveyed serving a population of 18 million. Of the 954 systems 869 did not meet bacteriological surveillance criteria. The importance of maintaining a chlorine residual was clearly demonstrated. The data showed that unless a chlorine residual was maintained in the distribution system, a significant percent of the samples would not meet the bacteriological standard. Water-borne outbreaks of disease caused by contamination of the distribution system through cross connections and back siphonage have been recorded since the beginning of the twentieth century and still occur today. Water borne disease outbreaks in the U.S. for the period 1961-1970 included gastroenteritis of unknown etiology, infectious hepatitis, shigellosis, typhoid fever, salmonellosis, infections of enteropathogenic *E. coli,* giardisis and amebiasis (Craun and McCabe, 1973). Craun and McCabe (1973) state that "the major cause of outbreaks in public systems is through contamination of the distribution system - primarily via cross connections and back siphonage". For the period 1946-1970, 39.4% of the total number of outbreaks in public systems were caused by contamination of the distribution system. Only 6.6% of the total cases of illnesses resulted from these outbreaks, since the contamination of a part of the distribution system usually affects less people than contamination of the water source or breakdowns in treatment. However, distribution system deficiencies have contributed a greater number of cases in recent years. In municipal water systems during 1971-1977, the percent of outbreaks caused by distribution system contamination remained fairly constant compared to 1946-1970 to wit: 37% compared to 39.4%, but the percentage of cases of illnesses increased from 6.6% to 38% (Craun, 1978). When infectious hepatitis alone is considered, contamination of the distribution system is the major cause both in numbers of outbreaks and numbers of cases. In public systems, such contamination resulted in 10 of 17 outbreaks and 295 of 739 cases, for 1946-1970. For 1971-1974, 5 additional outbreaks of infectious hepatitis occurred in public systems, of which one was caused by distribution system deficiences (Craun *et al.*, 1976).

In addition to the overt outbreaks caused by the pathogens mentioned above, other microorganisms found in samples from the distribution system may cause health problems to compromised individuals, particularly, the infirm in hospitals and individuals taking immuno-suppressive drugs. These microorganisms include species and strains of *Pseudomonas, Flavobacterium, Aeromonas* and *Klebsiella*. (Geldrich, 1973).

The maintenance of a chlorine residual, particularly a free residual, throughout a community water distribution system has been shown to be effective in meeting bacteriological standards (Buelow and Walton, 1971) and in controlling the general bacterial population within distribution lines (Geldrich *et al.*, 1972). Since the water leaving a treatment plant with accepted treatment practices is almost without exception of good bacteriological quality, the superior quality of distribution system samples in systems that maintain chlorine residuals must be due to the protection of the residual against bacterial regrowth and post-treatment contamination. Direct evidence of the role of the chlorine residual in the water distribution system so far as in the literature is limited.

SECTION 2

CONCLUSIONS

1. Chlorine residual is functional in the distribution system and provides protection against post-treatment contamination.

2. A free chlorine residual is more effective in neutralizing microorganisms contained in the contaminant than combined residual chlorine.

3. A free chlorine residual noticeably decreases when challenged with a contaminant and does serve as a flag.

4. Increased plate count levels were associated with decreased chlorine residuals and with increased turbidity.

5. The maintenance of a free chlorine residual is the single most effective measure for controlling the concentration of plate count microorganisms in the distribution system.

6. A variety of bacterial types, as determined by seven biochemical tests, is to be found in the distribution system. At any given sample station, it is likely that 3 or 4 of these groups will predominate in number and frequency of occurrence.

7. The biochemical groups isolated at 35°C and 20°C were similar.

SECTION 3

RECOMMENDATIONS

It would appear that the current water works practice of maintaining some kind of a chlorine residual within the distribution system is justified on the basis of operational data and reinforced by the results of this study. The disinfecting superiority of free over combined chlorine species came as no surprise. The inability of combined chlorine residuals to function as a "warning flag" that abnormalities have occurred within the distribution piping was not expected. The possible adverse effects of residuals in the distribution system have got to be examined. These effects are the long standing debate of contribution to chloro-tastes whether free, mono or dichloramine or nitrogen trichloride is responsible and the effect of producing hazardous by-products.

It should be apparent that not all distribution systems can achieve and maintain a persistent free or sometimes even a combined chlorine residual. More information is needed to characterize such distribution systems. It could be the lay-out (lack of circulation), pipe materials, age of system, water quality and degree of corrosion or deposition. The older systems in the northeastern towns and cities many beyond 75 years of age, are available for such study. It may well turn out that water quality may not be as important as the need to completely renovate the older pipe system. The cost will be large and efforts to study the causes with view of prevention might be the best immediate course to pursue.

SECTION 4

DESCRIPTION OF STUDIES

This project was designed to provide microbiological, physical and chemical evidence obtained from controlled laboratory experiments, pilot reservoir studies and municipal distribution system observations to evaluate the benefits, if any, of the maintenance of a free or combined chlorine residual in public water supplies.

HOLDING TANK STUDIES

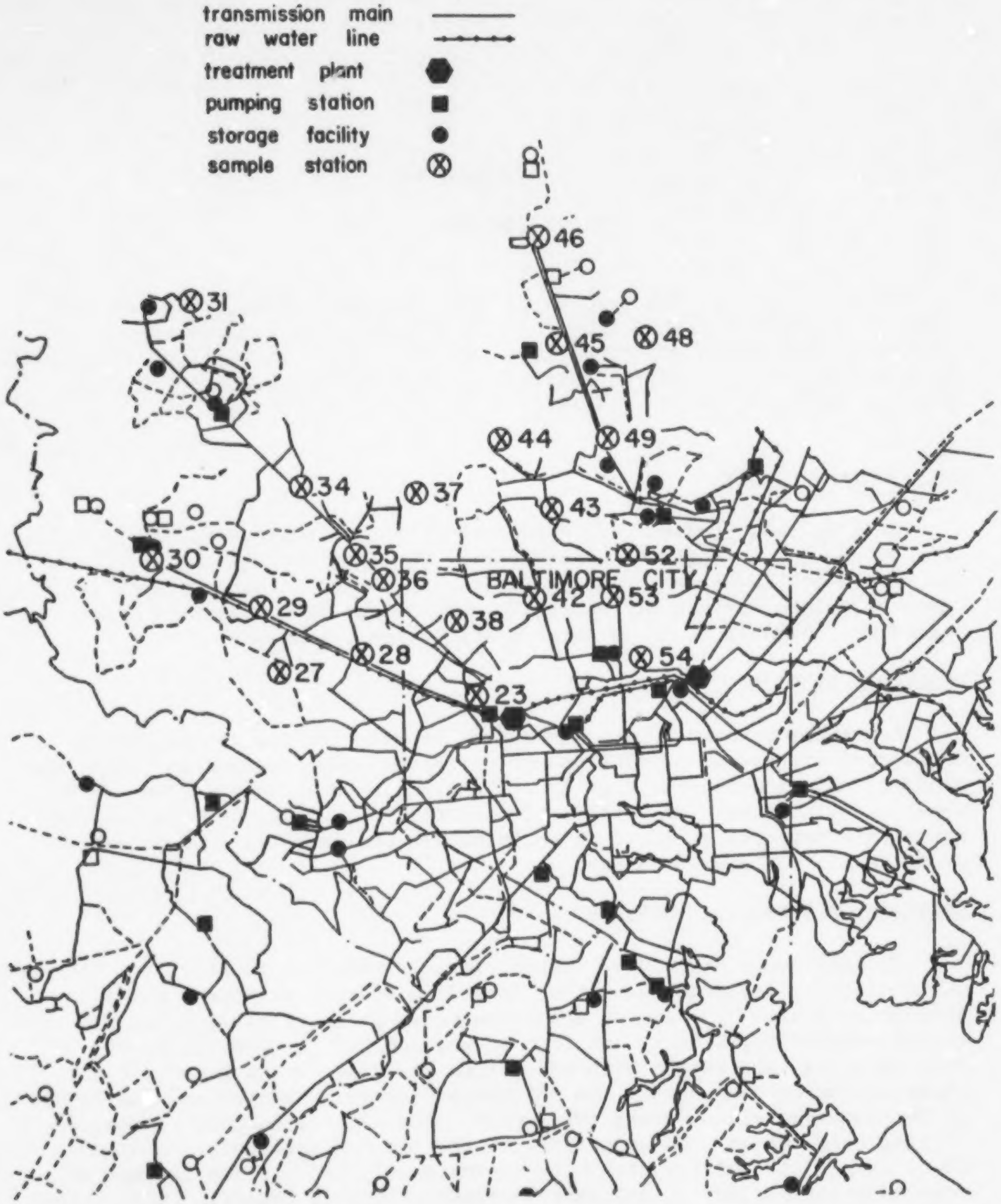
Holding tank studies were conducted to obtain basic data on the relative volume and strength of contamination that can effectively be neutralized with low levels of chlorine residuals. Relative survivals of indicator organisms, pathogenic bacteria, and viruses were evaluated under conditions commonly found in water distribution systems.

RESERVOIR STUDIES

Reservoir studies were conducted to provide information on the inactivation of natural populations of coliforms under conditions where the residual chlorine was continually replenished by reservoir inflow as the water was withdrawn. The effect of naturally occurring turbidity on the protective capacity of residual chlorine was evaluated with water taken from the Little Patuxent River.

MUNICIPAL DISTRIBUTION SYSTEMS

The Baltimore City water system provides services to Baltimore City and parts of the surrounding counties, including Howard, Baltimore and Anne Arundel counties. The system takes raw water principally from two protected reservoirs, Liberty and Loch Raven, and has the capability of supplementing this supply with water from the Susquehanna River. Figure 1 shows the major elements of the Baltimore City water system and the location of the sampling sites during this study. Two water treatment plants, employing coagulation, sedimentation, filtration and breakpoint chlorination, supply the service area with approximately 250 million gallons of treated water per day. (Baltimore Regional Planning Council, 1972). The Montebello treatment plant, located adjacent to sampling site 54 in Figure 1, supplies water to the heavily industrialized southern and southeastern parts of the metropolitan area. The Ashburton treatment plant, located adjacent to sampling site 23, supplies water to the rest of the system. In


transmission main
raw water line
treatment plant
pumping station
storage facility
sample station
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31
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48
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BALTIMORE CITY
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54
27
23

Figure 1. Major elements of the Baltimore, Maryland water treatment and distribution system.

the distribution system are facilities for storage of treated water, in open reservoirs or in elevated tanks with provisions for rechlorination. The majority of the distribution mains in the Baltimore system are unlined cast-iron pipe. There are approximately 1,500 to 2,000 miles of unlined pipe in the system (Stewart, 1971).

Twenty-one sampling sites were selected for weekly monitoring based on chlorine residual data for the previous year from the records of the City of Baltimore Bureau of Operations, Water Division. The average monthly free chlorine residual over the sampling period for each station is shown in Table 1. The sites were chosen so that as wide a range of free chlorine residuals as possible would be obtained. The range was from an average of 0.01 mg/liter from a station that frequently showed no free residual to 0.91 mg/liter from a station that consistently showed high free chlorine residuals.

Frederick, Maryland is located approximately 50 miles northwest of Baltimore. The water supply and distribution system provides service to a population of 30,000. The city gets water from four sources, two upland sources receive no treatment other than chlorine and ammonia addition, at a ratio of 6:1 (Cl:N) by weight. The other two sources receive conventional complete treatment. The four sample sites chosen for this study are on the western side of Frederick, and receive primarily the chlor-ammoniated water from the upland sources, although some mixing occurs in the distribution system depending on local demand. Most of the pipes in the Frederick distribution system are cement lined cast iron. Since the time of this study, the ammonia addition procedure has been terminated and a free chlorine residual is maintained in the Frederick distribution system.

TABLE 1. AVERAGE MONTHLY FREE CHLORINE RESIDUAL FOR SAMPLING STATIONS IN THE BALTIMORE DISTRIBUTION SYSTEM DURING THE SAMPLING PERIOD (JULY 1977 TO JUNE 1978)

Sample Station	July 1977	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June 1978	Yearly Average
23	.85	.93	.93	.83	.82	.94	.86	.85	.80	.80	.86	.63	.86
27	0	0	0	0	0	.15	.23	.21	.11	.03	0	0	.06
28	.38	.37	.36	.40	.44	.50	.70	.40	.35	.33	.50	.10	.40
29	.36	.28	.30	.35	.47	.56	.52	.44	.38	.31	.34	.35	.38
30	.10	.24	.23	.31	.60	.68	.65	.55	.49	.34	.32	.13	.38
31	0	0	.06	.03	0	.14	.14	.19	.21	.10	0	.06	.07
34	.13	.33	.40	.21	.25	.44	.33	.30	.46	.19	.17	.19	.28
35	.21	.29	.19	.09	.07	.26	.43	.25	.20	.06	.09	.13	.18
36	.80	.82	.85	.88	.88	.91	.87	.81	.80	.80	.80	.74	.83
37	0	0	0	0	.11	0	.09	0	0	.11	0	0	.02
38	.72	.61	.71	.68	.65	.68	.75	.68	.80	.61	.73	.38	.66
42	.55	.43	.44	.48	.46	.61	.55	.59	.52	.40	.49	.39	.49
43	.55	.26	.29	.35	.42	.53	.53	.53	.57	.36	.43	.25	.42
44	0	0	0	.03	0	.01	.04	.01	0	.14	0	0	.01
45	.95	.86	1.05	1.00	1.06	.89	1.09	1.00	.78	.63	.83	.74	.90
46	.75	.81	.93	1.00	.76	.60	.96	.74	.66	.63	.66	.76	.77
48	0	0	0	0	0	.01	.40	.01	0	0	0	0	.03
49	.93	1.04	1.10	1.20	.83	.81	.94	.74	.80	.74	.97	.90	.91
52	.59	.68	.76	.74	.61	.90	.96	.55	.79	.68	.80	.74	.73
53	.08	0	.02	.03	.19	.21	.34	.38	.38	.17	.21	.04	.17
54	.74	.49	.68	.59	.75	.61	.53	.74	.79	.59	.63	.61	.64

SECTION 5

METHODS

HOLDING TANK STUDIES

Contaminant Evaluation

Autoclaved raw sewage, seeded with the test microorganisms, was used as the contaminant material in batch studies. Since the quality of sewage arriving at a sewage treatment plant changes from day to day and from hour to hour, it was necessary to use one sample of sewage for several experiments so that valid comparisons could be made between experimental runs. The effect of autoclaving and subsequent storage of the sewage was evaluated.

Raw sewage was collected from the Ft. Meade, Maryland sewage treatment plant #2. The sewage sample was thoroughly mixed and dispensed in 2.5 liter aliquots. Half of the sewage sample was autoclaved at 121°C for 70 minutes. Thee other half was left unautoclaved. Both sewages were then stored at 4°C until their use. All chemical and physical tests were performed according to procedures in Standard Methods (1975). Ammonia and organic nitrogen were determined by the Kjeldahl distillation procedure. Total carbon analysis was performed with a Beckman total carbon analyzer. Turbidity was determined with a Hach model 2100A turbidimeter. Total solids, total volatile solids, suspended solids, pH, and biochemical oxygen demand (BOD) were determined according to standard procedures. Determination of the chlorine dosage required to reach breakpoint (the amount of chlorine necessary to produce a free chlorine residual) was performed in 250 ml bottles into which the raw autoclaved or unautoclaved sewage was dispensed. Sodium hypochlorite solution in varying amounts were added to the bottles to give a range of chlorine dosages. After 30 minutes contact time at room temperature these samples were tested for total chlorine residual by the starch iodide titration method (Standard Methods, 1975), and checked for the presence of free chlorine by a modification of the leuco crystal violet method (Olivieri *et al.*, 1971). pH readings were also made. These chemical and physical tests were performed on the autoclaved and unautoclaved sewage on the day of collection and at varying times up to 23 days after collection.

Isolation and Enumeration of Bacteria

Bacteria were isolated from settled sewage drawn from the Baltimore Back River sewage treatment plant.

Coliform--

An organism of the coliform group (coliform) was isolated from confirmatory brilliant green lactose bile broth by streaking on eosin methylene blue (EMB) agar and differentiated according to Standard Methods (1975) on the basis of indole, methyl red, Voges-Proskauer, and citrate utilization (IMVIC). An isolate yielding typical green, shiny colonies on EMB and displaying the classical ++-- IMVIC reaction was chosen for use in subsequent studies.

Salmonella typhimurium--

Concentration and enrichment procedures and biochemical identification were performed according to Olivieri (1977). Isolates which were phenylalanine deaminase, oxidase and malonate negative, positive for mannitol fermentation and lysine decarboxylase, and yielded typical *Salmonella* reactions on triple sugar iron agar and lysine iron agar were chosen for serological testing. Serological identification was performed according to the methods of Edwards and Ewing (1972) using Difco antisera. An isolate, which was positive for somatic antigens poly O and group B and was found to contain H anigens i in phase 1 and 1 in phase 2, was chosen for use in subsequent studies.

Shigella--

The concentration and enrichment procedures of Olivieri (1977) were used in attempts to isolate *Shigella* from sewage. Since these attempts were unsuccessful, a laboratory strain of *S. sonnei* was used in the studies.

The three bacterial organisms noted above were tested for susceptibility to f2 bacteriophage by plating each by the agar overlay technique against a known high titer f2 stock. All three were found to be non-susceptible.

Bacterial cultures used in all subsequent inactivation studies were grown overnight at 35°C in Brain Heart Infusion (BHI) broth, washed 3 times by centrifugation and finally resuspended in a volume of saline equal to that of the original culture.

The feasibility of using xylose lysine (XL) agar (Difco, 1972) for the simultaneous determination of levels of coliform, *S. typhimurium* and *S. sonnei* was evaluated. Bacterial cultures were grown overnight on tryptone yeast-extract (TYE) broth at 35°C. Bacterial numbers for each culture were determined separately by pour plates on TYE agar and by spread plates on XL agar. The coliform, *S. typhimurium* and *S. sonnei* cultures were then mixed and the mixture was plated on XL agar. On XL agar, coliform colonies were yellow, *S. sonnei* colonies were pinkish-red, and *S. typhimurium* colonies were black. The results of the determination of bacterial numbers for the separate cultures and for the mixture of the three cultures are shown in Table 2. The XL agar gave comparable recoveries to the TYE agar when bacteria were plated separately. The determination of bacterial numbers in the mixed cultures on XL agar gave results comparable to plating each strain separately on XL agar or TYE agar. No interference was observed upon plating the mixed culture. Thus, plating on XL medium was found to be a simple and effective method for determining bacterial numbers in a mixed culture of coliform organism, *S. typhimurium* and *S. sonnei*. This technique

TABLE 2. COMPARISON OF TYE AND XL MEDIA FOR THE ENUMERATION OF COLIFORM, *S. typhimurium*, AND *S. sonnei*, AND THE EFFECT OF MIXING THE THREE ORGANISMS ON THE RECOVERY ON XL AGAR

Bacterial Strain	Media	Number/ml Run 1	Number/ml Run 2	Number/ml Run 3
coliform	TYE	2.8×10^8	1.9×10^8	1.7×10^8
	XL	2.5×10^8	1.8×10^8	1.2×10^8
In mixture	XL	3.5×10^8	2.0×10^8	1.2×10^8
S. typhimurium	TYE	2.4×10^8	2.2×10^8	2.6×10^8
	XL	3.0×10^8	2.3×10^8	1.9×10^8
In mixture	XL	3.2×10^8	2.6×10^8	1.8×10^8
S. sonnei	TYE	2.3×10^8	2.2×10^8	2.4×10^8
	XL	3.0×10^8	2.0×10^8	2.2×10^8
In mixture	XL	2.1×10^8	2.6×10^8	2.1×10^8

was used throughout the subsequent studies.

Preparation and Enumeration of Viruses

The f2 bacterial virus was obtained from the American Type Culture Collection (ATCC # 15766-B) and virus stocks were prepared by the method given by Cramer (1976). The f2 virus was assayed by the agar overlay technique (Adams, 1959) using *E. coli* K-13 (ATCC #15766) as the host bacterium.

Poliovirus 1 (vaccine strain) was prepared in Buffalo green monkey (BGM) cells (Dahling *et al.*, 1974) grown in roller bottles in Eagle's minimal essential medium containing 5% fetal calf serum. The poliovirus was grown without antibiotics, since the presence of antibiotics would preclude mixing the poliovirus with the bacterial strains in the inactivation experiments. The virus was harvested by three cycles of freeze thawing, followed by centrifugation to remove cell debris. Poliovirus plaque assays were done using BGM cells. All experiments were performed using aliquots from a single virus preparation.

Experimental Procedures

A 30 liter volume of Baltimore City tap water was drawn and brought to the desired temperature. The chlorine residual was measured by amperometric titration (Standard Methods, 1975) using a Sargent-Welch Model XVI polarograph with dual platinum electrodes and adjusted to the level for the experiment with the addition of sodium sulfite or chlorine as required. When a combined chlorine residual was desired, ammonium chloride was added to a three-fold molar excess of ammonia. The water was buffered by the addition of 0.001M phosphate and the pH was also adjusted. The schematic of the procedures used during the experimental runs is shown in Figure 2. Aliquots of 4 liters were dispensed into polypropylene containers and held in a constant temperature water bath. The pH and temperature of the autoclaved raw sewage were adjusted and the sewage was seeded with test organisms (coliform, *S. typhimurium, S. sonnei,* f2, and poliovirus 1). At time zero, predetermined amounts of seeded sewage according to test protocol were added to the tap water with mixing. Samples for the determination of microbial survivals were withdrawn into tubes containing an excess of sodium thiosulfate at 2, 30, 60 and 120 minutes contact time. Chloroform (2-3 drops) was added to the sample prior to viral analysis to eliminate interference from bacteria. Analysis for chlorine residual by amperometric titration was performed in all trials at 2 and 120 minutes after the addition of sewage, and in some trials the residual chlorine was measured at 2, 30, 60 and 120 minutes.

Levels of seeded, autoclaved raw sewage added to the tap water for each of the experimental conditions are shown in Table 3. Experimental runs were performed at either pH 6 or 8, at temperatures of 0, 10, 20 and 30°C, and with initial free or combined chlorine residuals of approximately 0.2 and 1.0 mg/liter.

Holding tank studies were divided into 4 sections. In each section the experimental design was to compare the effect of one variable, with other

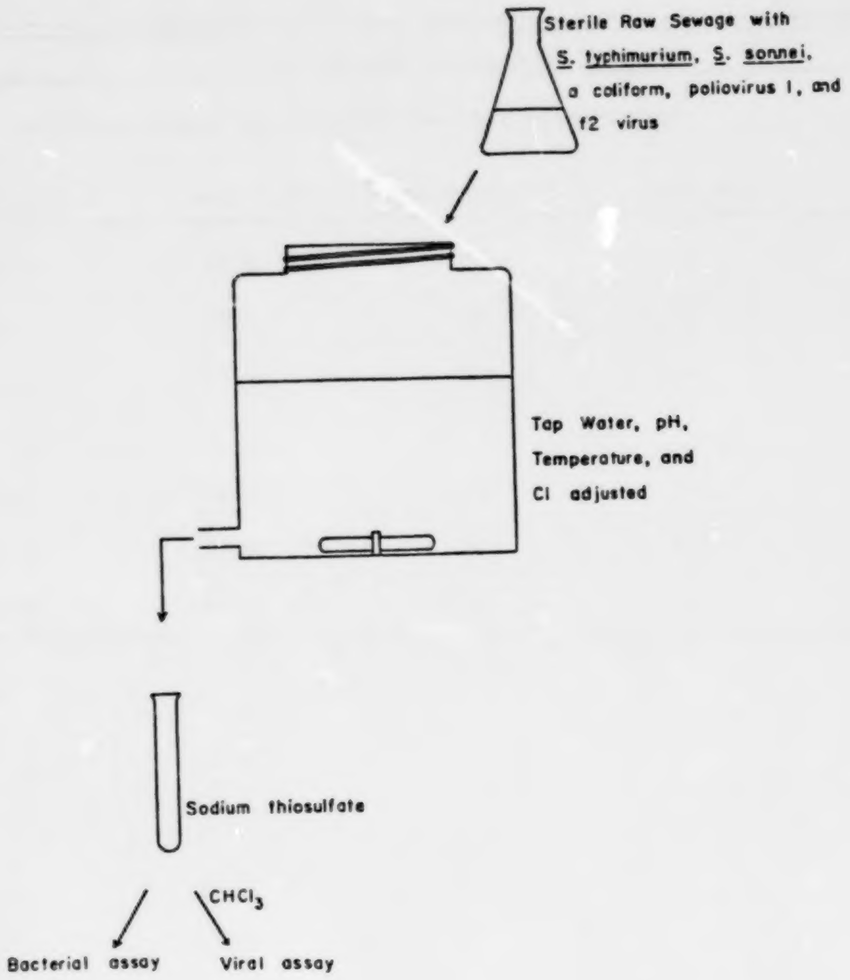
Sterile Raw Sewage with
S. typhimurium, S. sonnei,
a coliform, poliovirus I, and
f2 virus
Tap Water, pH,
Temperature, and
Cl adjusted
Sodium thiosulfate
$CHCl_3$
Bacterial assay
Viral assay

Figure 2. Schematic - Holding tank experimental protocol.

TABLE 3. PERCENT AUTOCLAVED RAW SEWAGE ADDED TO TAP WATER FOR EACH OF THE EXPERIMENTAL CONDITIONS

	% Autoclaved Raw Sewage			
	Approximate Initial Chlorine Residual, mg/liter			
	1.0 Free	1.0 Combined	0.2 Free	0.2 Combined
pH 6	1%	1%	0.1%	0.01%
	5%	5%	0.5%	0.05%
	10 %	10%	1.0%	0.1%
pH 8	1%	1%	0.1%	0.01%
	5%	5%	0.5%	0.05%
	10%	10%	1.0%	0.1%

conditions being held constant. The first section dealt with the effect of pH on the efficiency of microbial inactivation when starting with an initial combined chlorine residual. Each run consisted of three paired trials, with the percent sewage constant for each pair and the pH at either 6 or 8. In the second section the effect of the initial chlorine species (free or combined) was compared with pH held constant. The third section was similar to the first, except that the initial chlorine residual in the experiment was the free species. In the fourth section, pH, chlorine species, and percent sewage added were held constant and the initial chlorine residual was varied. This section was designed to facilitate the construction of concentration-time relationship plots.

Extended Time Studies--

At the end of the 2 hour contact time, 500 ml samples were taken without dechlorination from each sewage-tap water mixture. These samples were held at the temperature of the experimental run for seven days and were monitored for increases or decreases in bacterial numbers.

RESERVOIR STUDIES

Experimental Procedure

Reservoir studies were similar to the holding tank studies described above. These studies differed principally in that:

1. the sample volume withdrawn was replaced with an equal volume of fresh chlorinated water.

2. larger volume tanks were used.

3. raw (unautoclaved) sewage was used as the contaminant.

4. the sewage was not seeded with bacteria, and naturally occurring coliforms were assayed, and

5. the pH 6 and low (0.2 mg/liter) chlorine residual studies were omitted.

Reservoir studies were done using two sources of water: tap water from the Ft. Meade, Maryland water distribution system and water from the Little Patuxent River. The Little Patuxent serves as the source of raw water for the Ft. Meade water system. The reservoir system used in these experiments consisted of two 1500 liter tanks and six 120 liter tanks. The 1500 liter tanks were filled with the desired water and the pH was adjusted with concentrated sulfuric acid or saturated sodium hydroxide. The chlorine residual was adjusted to approximately 1.0 mg/liter by the addition of sodium sulfite or aqueous chlorine. When a combined chlorine residual was desired, ammonium chloride was added to a 3-fold molar excess of ammonia. In runs using tap water, one 1500 liter tank was adjusted to a combined residual and one to a free residual. Three of the 120 liter tanks were filled with 100 liters of water with a free residual and three 120 liter tanks were filled with 100 liters of water with a combined residual. Raw sewage was collected from Ft. Meade sewage treatment plant #2 and was seeded with f2 bacterial virus. At time 0, varying amounts of the sewage (1-10%) were added to each of the six tanks and the contents were mixed. Samples were withdrawn by a spigot at the bottom of each tank. The total volume withdrawn at each sample time was 25 liters. The first 4 liters were collected for physical measurements and chemical analysis (pH, turbidity, free and total chlorine, temperature), the next 4 liters were collected for biological analysis, (coliform and f2) and 17 liters were run to waste. The tanks were then refilled to the 100 liter mark with the same water that they originally contained. Samples were analyzed for free chlorine by the leuco crystal violet method and for total chlorine by the iodometric method. Turbidity was determined with a Hach model 2100A turbidimeter. Coliforms were determined using a 5 tube MPN procedure with lactose broth. All positive tubes were confirmed in BGLB. f2 was titered by the agar overlay method.

In runs using both tap and river waters, one 1500 liter tank was filled with tap water and one with river water and the chlorine residual and pH were adjusted. Two of the 120 liter tanks were filled with 100 liters of tap water, two with 50 liters of tap water and 50 liters of river water, and two with 100 liters of river water. In these runs, a constant percent sewage was added to the tanks, thus, each run consisted of 3 trials with 2 replicates. The sampling procedure was the same as that mentioned above.

Experiments were designed to evaluate the degree of mixing produced by the addition of the contaminant, withdrawal of sample, and subsequent refilling. One liter of fluorescein dye was poured into each of the 6 tanks, without mixing. Aliquots of 25 liters were then taken from 5 of the tanks, following the sampling procedure given above. Each sample was mixed, and the absorbance at 480 nm was determined. The concentration of fluorescein dye in the sample was calculated from the calibration curve shown in Figure 3. One of the tanks served as a control to evaluate any loss of fluorescein over the sampling period. Figure 4 compares the results obtained with the theoretical results expected if the tanks were completely mixed. The theoretical line was obtained by multiplying the control value by the dilution factor. The results indicate that, even without mixing, the dye becomes distributed uniformly throughout the tank after addition, and that it redistributes itself uniformly after each withdrawal and refilling. The reservoir studies were originally designed without mixing, in order to simulate the manner in which a contaminant enters the distribution system. Since it was found that the tanks became thoroughly mixed by sample withdrawal and refilling, a manual mixing step was included to insure reproducible conditions.

MUNICIPAL DISTRIBUTION SYSTEMS

Sample Collection and Analysis

Tap water samples were collected from the Baltimore, Md. and Frederick, Md. water distribution systems in sterile polyethylene bottles containing sodium thiosulfate and were kept in an ice chest until processing. The maximum time between sample collection and analysis was 8 hours. Sample site designations in Baltimore are those used by the Baltimore City Water

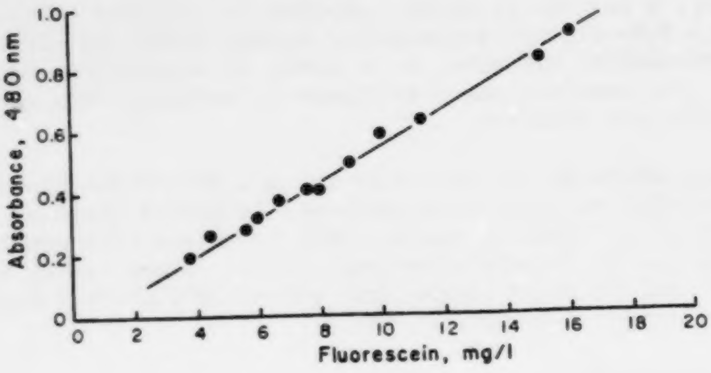

Figure 3. Calibration curve for the determination of fluorescein concentration.

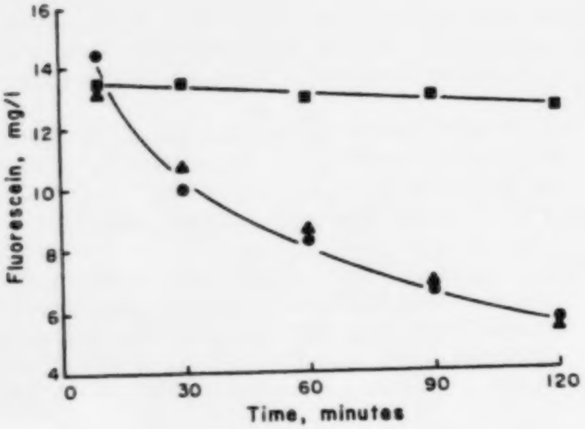

Figure 4. Effect of sample collection and refilling on the concentration of fluorescein dye in the reservoir studies. —▲—, results expected by dilution for a completely mixed system. —●—, observed result. —■— control.

Department, since these samples were collected by personnel of that department in conjunction with their regular sampling program. Chlorine residual data and temperature were determined by the sample collector. Since great reliance was to be placed on the chlorine residual data obtained by the sample collector, a laboratory study comparing the results obtained by the collector with a N_1N_1-diethyl-p-phenylene diamine (DPD) kit with the results obtained by amperometric titration on a series of chlorinated water samples was performed. The results, shown in Figure 5, indicate that good correlation (R = 0.988) was obtained.

Samples were analyzed for turbidity using a Hach-Model 2100A turbidimeter and total coliform tests were performed in lauryl tryptose broth using a five tube most probable number (MPN) technique with sample volumes of 10.0, 1.0 and 0.1 ml (Standard Methods, 1975). Plate counts were done at 35°C after 48 and 96 hours incubation, and at 20°C after 9 days incubation, using plate count agar (Difco, 1972).

Microbial Differentiation

Isolates obtained from 8 of the sampling sites on plate count agar at 20°C and 35°C were subjected to a biochemical screening procedure. The sampling sites involved were numbers 1 and 4 in Frederick and numbers 27, 34, 37, 43, 44 and 48 in Baltimore. A maximum of 48 colonies from each site, 24 at each temperature, were screened for catalase activity, oxidase, motility, indole production, and aerobic and anaerobic utilization of glucose (OF test). In the later months of the study, colonies were also screened for growth on Simmons citrate and MacConkey agar and for nitrate reduction.

Colonies were picked at random onto a master plate of plate count agar and allowed to grow. A toothpick replicator (Markowitz 1977) was used to transfer an innoculum from the master plate to 24 well CoStar tissue culture dishes. Each well contained 2 ml of the appropriate agar media. A second master plate was innoculated at the end of each run to insure that a sufficient innoculum was carried to each plate. Colonies subject to the following tests were incubated at the temperature at which they were first isolated. Recommended incubation time for testing oxidase and catalase activity is 18-24 hours. However, slow growing colonies were incubated for up to 96 hours. Positive and negative control cultures were routinely included for each test.

Since the toothpick replicator is relatively new procedure, a comparison of this method with conventional tube methods (MacFaddin, 1976) was done. The results for 300 isolates from each temperature are shown in Table 4. Greater than 98% agreement between the two methods was obtained for aerobic and anaerobic production of acid from glucose and production of indole. The lowest agreement was in the detection of anaerobic growth, with 92.5% at 20°C and 93.1% at 35°C. Biochemical tests were performed according to the following procedures:

Catalase--

Several drops of 3% H_2O_2 were added to each colony on nutrient agar containing 1% glucose. The evolution of gas was recorded as positive (MacFad-

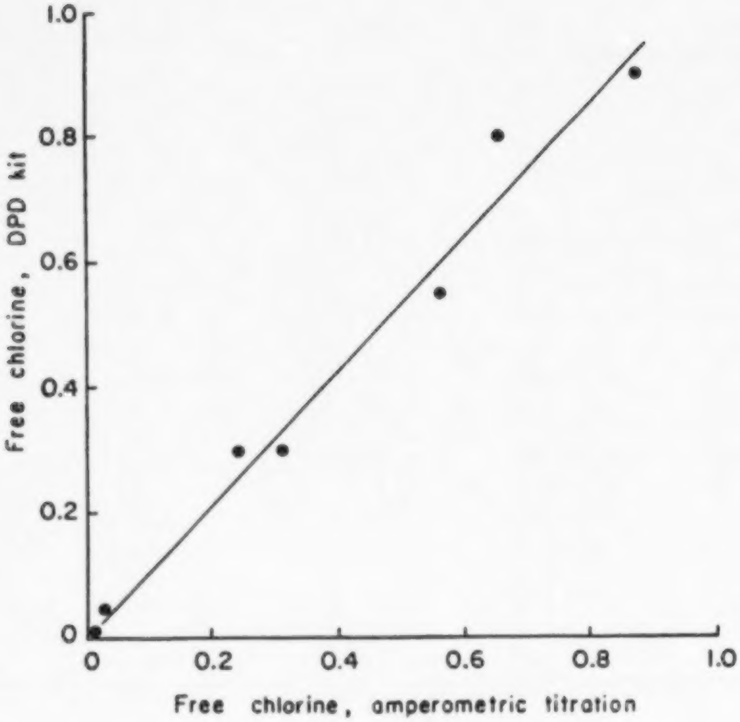

Figure 5. Free chlorine residual determination by sample collector with DPD versus free chlorine determination by amperometric titration.

TABLE 4. COMPARISON OF THE TOOTHPICK REPLICATOR METHOD WITH CONVENTIONAL TUBE METHODS FOR BIOCHEMICAL TESTS FOR ISOLATES FROM PLATE COUNT AGAR AND KNOWN CONTROL CULTURES

Test	Temp °C	% agreement	Toothpick Replicator % False Positive	Toothpick Replicator % False Negative
Acid from glucose aerobically	20	99.4	0.6	0
	35	98.8	0.9	0.3
Acid from glucose anaerobically	20	100.0	0	0
	35	99.6	0.4	0
Anaerobic growth	20	92.5	3.3	4.2
	35	93.1	2.9	3.9
Motility	20	93.9	3.2	2.9
	35	96.1	2.1	1.8
Indole	20	99.7	.03	0
	35	99.7	0	.03

din, 1976).

Oxidase--

Equal volumes of 1% aqueous p-aminodimethylaniline oxalate and 1% alpha-naphtol in 95% ethanol were added to colonies grown on standard plate count agar. The development of a blue color within 2 minutes was recorded as positive. (Edwards and Ewing, 1972).

Indole--

Detection of indole was performed on SIM medium (Difco, 1953) using paper discs impregnated with Kovac's indole reagent. Development of a reddish-purple to red color within 3 minutes was recorded as positive. (MacFaddin, 1976).

OF Test--

Hugh and Leifson's OF basal medium was used to determine aerobic and anaerobic growth and utilization of glucose after 7 days incubation. Duplicate plates were innoculated, one incubated aerobically, and one anaerobically in a GasPak anaerobic system (MacFaddin, 1976).

Motility--

Motility was determined by spreading growth on SIM medium, after 4 to 6 days incubation. (Difco Manual, 1953).

The following tests were performed on isolates by conventional techniques in the later months of the study.

Nitrate Reduction--

Semisolid nitrate agar (0.5% agar, Difco) was innoculated by stabbing to the butt of the tube and streaking the slant. Incubation time was generally 24-48 hours, with some slow growing isolates incubated up to 9 days. Nitrate reduction was tested by the method given in MacFaddin (1976) using Naphthylamine hydrochloride reagent and 0.8% sulfanilic acid in 5N acetic acid.

Citrate--

The ability of isolates to use citrate as the sole carbon source was tested by innoculating Simmons citrate agar (Difco, 1953) and incubating it for up to 9 days. The development of a blue color was recorded as positive.

MacConkey--

The ability of the isolates to grow on MacConkey agar (Difco, 1972) was tested by innoculating slants and incubating them for up to 9 days. Growth and alkaline or acid reaction was recorded.

Gram Stain--

Isolates were stained by the procedure given in Standard Methods (1975). Positive lauryl tryptose tubes in the coliform assay were transferred for confirmation to brilliant green lactose broth (BGLB). Positive BGLB tubes were streaked onto eosin emthylene blue agar for isolation. Several isolates obtained on each plate that showed typical green shiny colonies were tested for IMVIC reactions and Gram stain. (Standard Methods, 1975).

SECTION 6

RESULTS

HOLDING TANK STUDIES

Contaminant Evaluation

The effect of autoclaving and subsequent storage of raw sewage on ammonia and total nitrogen, total carbon, turbidity, total solids, total volatile solids, suspended solids, pH, BOD, and the amount of chlorine required to reach the breakpoint was determined on initial sewage samples. These determinations were made on autoclaved and unautoclaved raw sewage on the day of collection and at elapsed times of 1, 3, 7, 11, 16 and 23 days.

The effect of steam sterilization and storage on the chemical parameters monitored is shown in Figure 6. Autoclaving the sewage resulted in an immediate increase in pH from 7.1 to 8.9. After this initial increase, the pH of the autoclaved and unautoclaved sewage remained constant over the 23 day period. Autoclaving and storage had no effect on total carbon, organic nitrogen, total and suspended solids, and biochemical oxygen demand (BOD). The turbidity of the unautoclaved sewage decreased from 65 nephelometric turbidity units (NTU) to 40 NTU, while the turbidity of the autoclaved sewage remained constant at 65 NTU.

Chemical parameters most important in the behavior of the simulated contaminant holding tank studies were ammonia nitrogen and chlorine breakpoint. The ammonia nitrogen concentration in the raw sewage increased from 20 mg/liter to 24 mg/liter over 23 days, while that of the autoclaved sewage remained constant at approximately 18 mg/liter. This increase in ammonia nitrogen in the raw sewage was followed by an increase in the breakpoint from 220 mg/liter to 260 mg/liter. The breakpoint for the autoclaved sewage remained constant at 210 mg/liter.

Differences in the stability of the breakpoint for the autoclaved and raw sewage are shown in the breakpoint curves in Figures 7 and 8. Figure 7 shows that the breakpoint for autoclaved sewage remains constant at 210 mg/liter and that the shape of the breakpoint curve does not change over the 23 day period. Figure 8 indicates that, in addition to the increase in the breakpoint dosage, the shape of the breakpoint curve changes substantially with time for the raw sewage.

The autoclaved raw sewage was found to be stable in those parameters important for the subsequent studies, and provided a reproducible source of

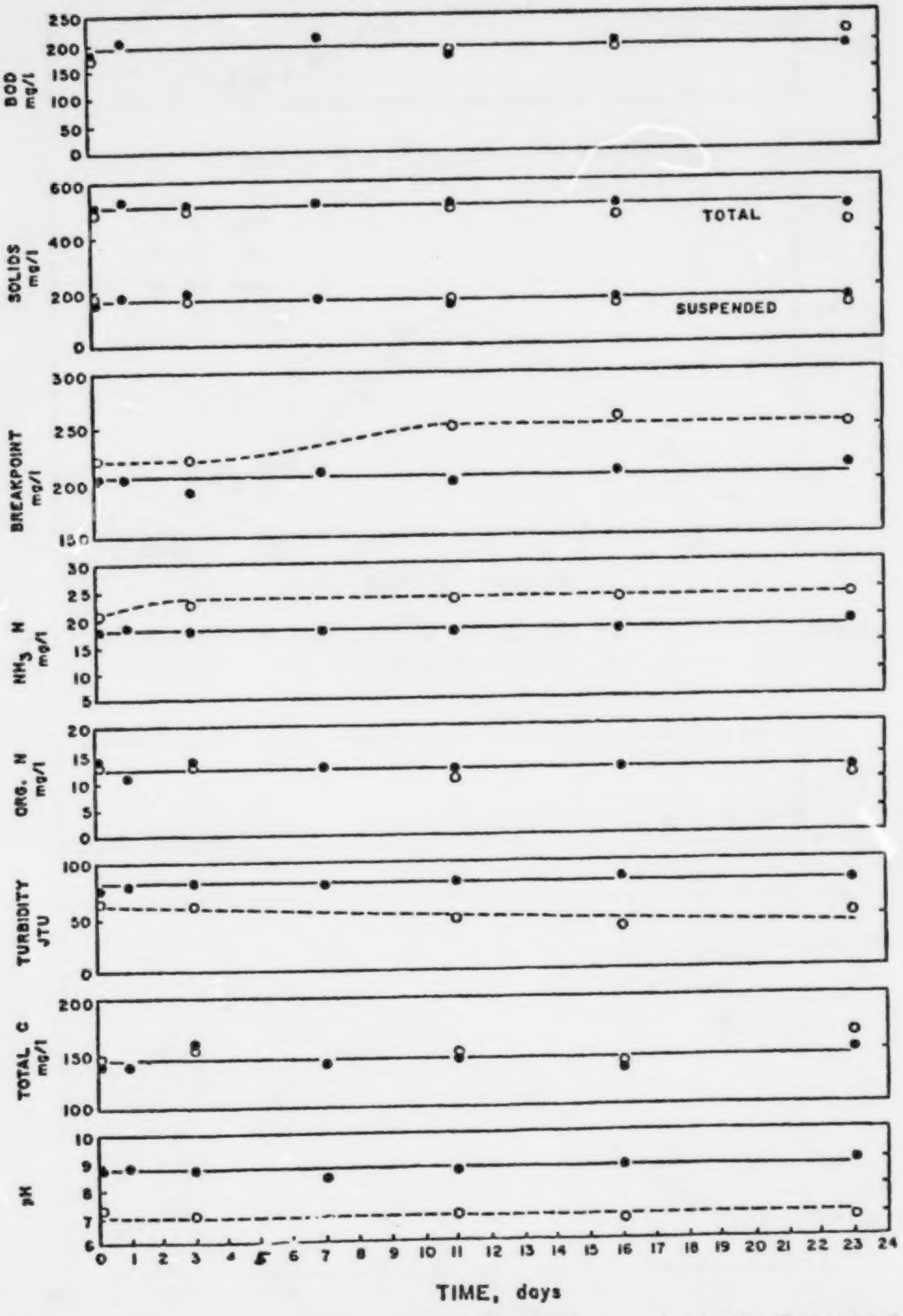

Figure 6. Effect of storage at 4°C on selected chemical parameters for raw sewage (○) and autoclaved raw sewage (●)

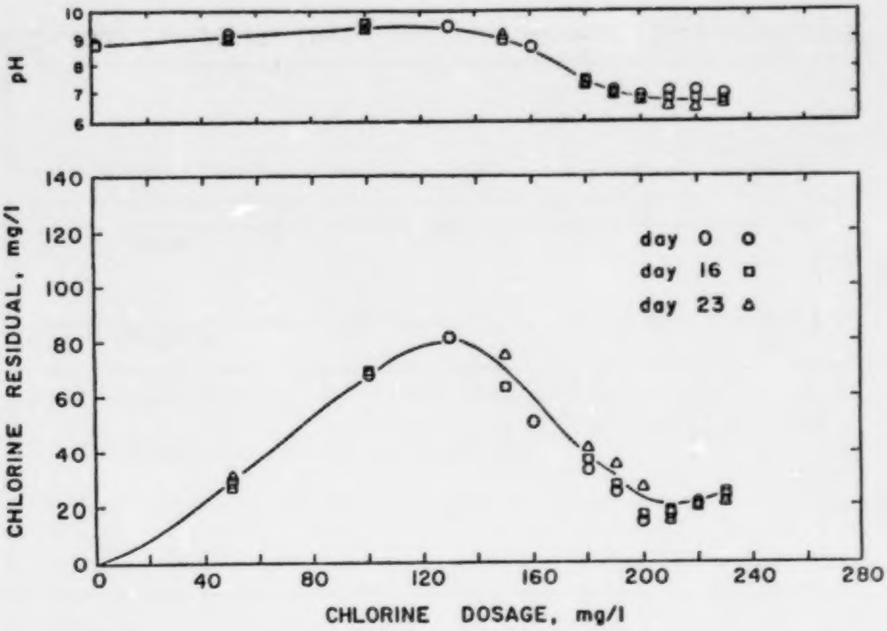

Figure 7. Effect of storage at 4°C on the chlorine breakpoint curve for autoclaved raw sewage.

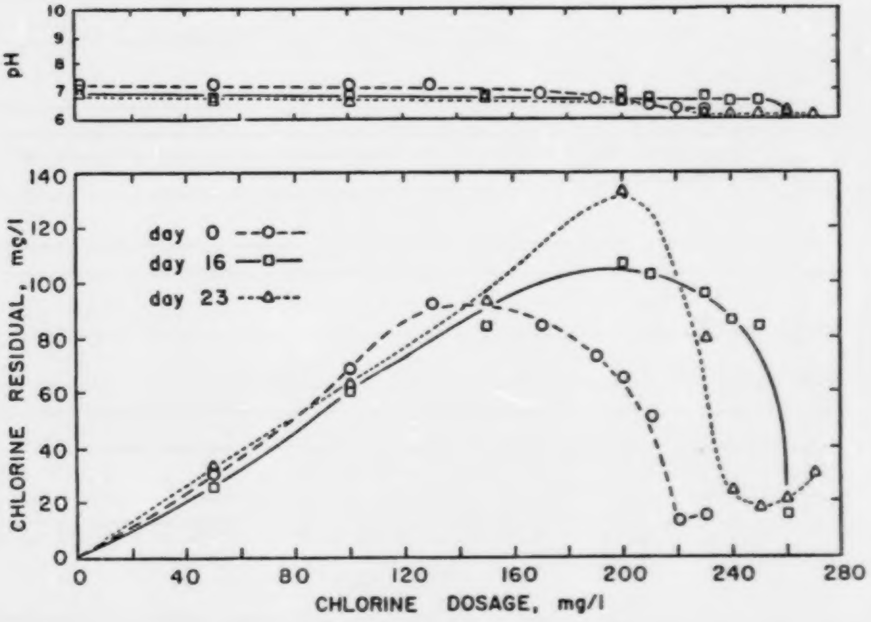

Figure 8. Effect of storage at 4°C on the chlorine breakpoint curve for raw sewage.

chlorine demanding material. Sewage collection was, therefore, done on a monthly basis, with one sewage sample used for the entire month.

Microbial Survival

The concentration-time relationship for 90% inactivation of the three test bacteria when 1 or 2% sewage was added to tap water containing an initial combined or free chlorine residual, respectively, is shown in Figure 9. The inactivation in this series of experiments follows the classical dependence on disinfectant concentration and contact time. Since the test microorganisms were mixed together, they were exposed to identical conditions, and valid comparisons of susceptibility can, therefore, be made. Little differences in the concentrations of chlorine and contact time required for inactivation were observed for the three bacteria. A note of caution should be made in the interpretation of this figure. The results obtained are dependent on the amount of sewage added, the characteristics of the sewage, and the initial species of chlorine employed. In the case where an initial free chlorine residual was used, the observed inactivation may be due to the momentary presence of free chlorine after the addition of the sewage, or to the resulting combined forms of chlorine.

The inactivation curves of the coliform organism, f2, and polio 1 under varying conditions of initial free or combined chlorine residuals and sewage levels are shown in Figures 10 through 12. Results shown are mean values of 4 to 8 trials, averaged over the 4 test temperatures (0, 10, 20 and 30°C) and utilizing different batches of sewage. Results for each individual trial are found in Appendix A. For clarity of graphical presentation, the results for *S. typhimurium* and *S. sonnei* were omitted, since these organisms behaved similarly to the coliform organism (shown above). The data for *S. typhimurium* and *S. sonnei* can also be found in Appendix A. Figure 10 shows the inactivation of the coliform, f2 and polio 1 at pH 8 in the presence of 1, 5 and 10% added sewage, with an initial free or combined chlorine residual of approximately 1 mg/liter. The results are plotted as log N/N_0, where N_0 is the number of microorganisms at time zero, and N is the number of microorganisms at any time t. An initial free chlorine residual was more effective than an initial combined chlorine residual for 1% sewage, with greater than 2.7 logs inactivation of the coliform in 30 minutes occurring with the free residual and 2.0 logs inactivation in 120 minutes occurring with the initial combined residual. The free residual was also more effective against f2 and polio at 1% sewage. At the higher sewage levels, the initial free and combined residuals were equally ineffective against the introduced microorganisms, with 0.5 log or less difference in the inactivation after 2 hours contact time. Both residuals decreased in effectiveness as the level of sewage was increased. At 10% sewage, less than 1 log bacterial inactivation and almost no f2 inactivation was obtained.

Figure 11 shows the inactivation curves of the coliform, f2 and polio virus 1 at pH 6 under the same conditions of sewage levels and initial chlorine concentration. An initial free chlorine residual was markedly more effective at this pH, with greater than 3 logs bacterial inactivation occurring in 2 minutes at 1% sewage and in 30 minutes at 5% sewage. The average bacterial inactivation with an initial combined residual with 1%

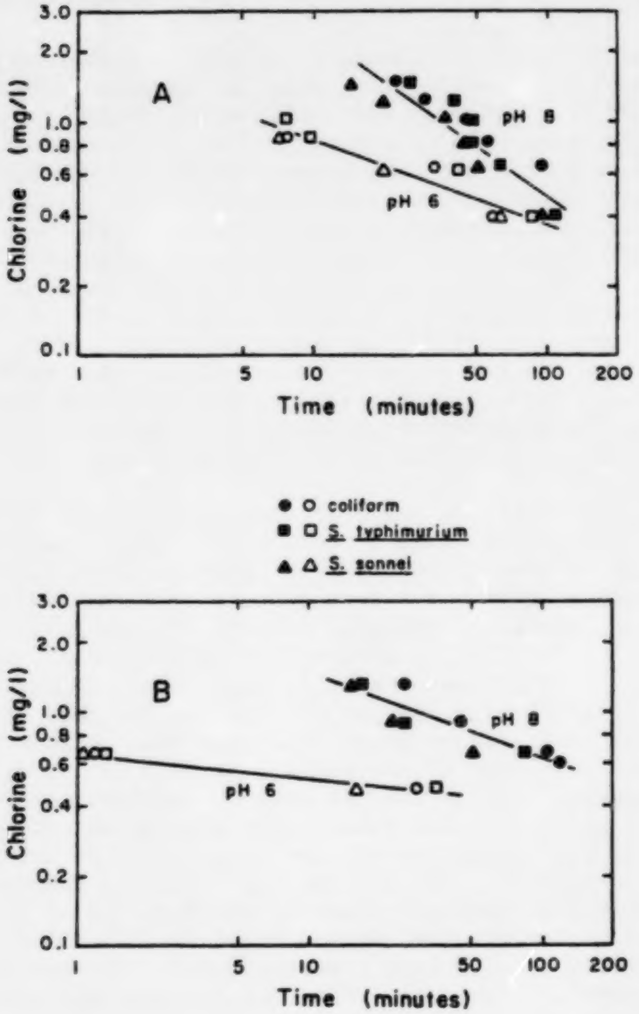

Figure 9. Concentration-time relationship for 90% inactivation of test bacteria, on the basis of the initial chlorine residual.
A. Initial combined chlorine residual, 20°C, 1% added sewage.
B. Initial free chlorine residual, 20°C, 2% added sewage.

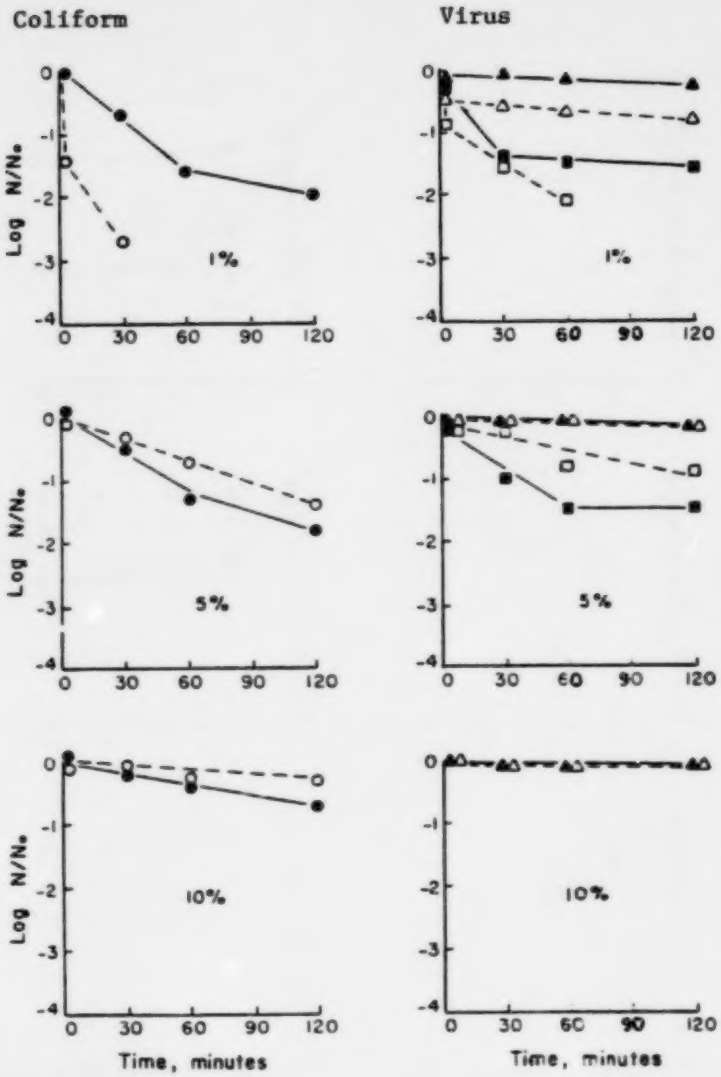

Figure 10. Inactivation of the coliform (○), f2 (△) and poliovirus 1 (□) by an approximate initial chlorine residual of 1 mg/liter in the presence of 1, 5 and 10% sewage at pH 8.0. Open symbols - initial free chlorine residual, average of 4 trials. Closed symbols - initial combined chlorine residual, average of 7 trials.

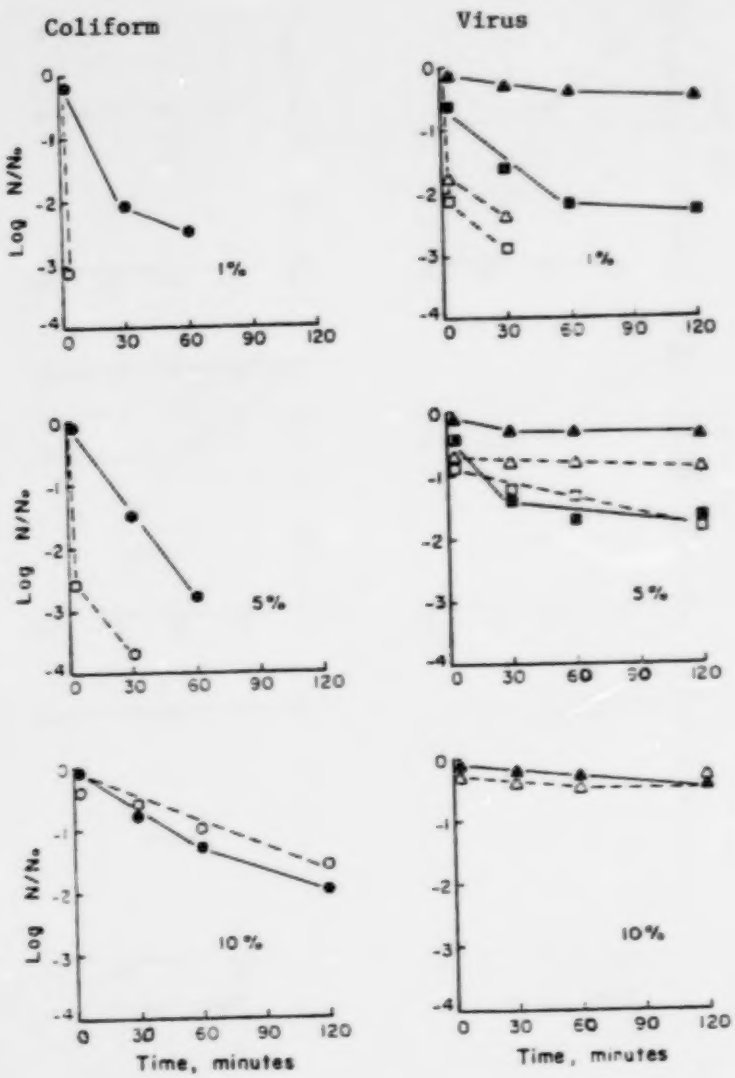

Figure 11. Inactivation of the coliform (○), f2 (△) and poliovirus 1 (□) by an approximate initial chlorine residual of 1 mg/liter in the presence of 1, 5 and 10% sewage at pH 6.0. Open symbols - initial free chlorine residual, average of 5 trials. Closed symbols - initial combined chlorine residual, average of 8 trials.

sewage at 2 minutes was 0.2 logs and with 5% sewage at 30 minutes the inactivation was 1.5 logs. The conditions of pH 6 and an initial free chlorine residual with 1% sewage was the only case where reductions of f2 and polio 1 to the lower sensitivity limit of the assay were obtained. A combined residual was ineffective against f2 under any of the conditions tested. Again, the efficiency of the residuals in inactivating the introduced microorganisms decreased as the sewage level increased, and the marked difference in the effectiveness of the free versus the combined residual disappeared.

Inactivation curves for 0.1% added sewage with an initial 0.3 mg/liter free or combined chlorine residual at pH 6 and 8 are shown in Figure 12. Data for 0.01 and 0.05% sewage with an initial combined residual and 0.2 and 0.5% sewage with an initial free chlorine residual are given in Appendix A. This disparity in sewage levels tested for the initial low level chlorine residuals is due to the fact that the difference in effectiveness of the free and combined residuals was more apparent at lower levels. Experimental conditions were set up to give a range of inactivation from slight inactivation to reduction to the sensitivity limit. This dictated the use of higher sewage levels when using an initial free residual. The comparable results shown in Figure 12 demonstrate the superiority of the initial free residual. The difference in inactivation is particularly evident at pH 6, where reductions of the coliform to the sensitivity limit of the assay occurred within 2 minutes with an initial free chlorine residual, while equivalent reductions with an initial combined residual required 2 hours.

The results shown in Figures 10 through 12 have been replotted in Figures 13 through 15 so that the effect of pH can be seen more readily. In all cases, whether starting with an initial combined or free residual, and at sewage levels of 0.1 to 10%, greater inactivation was observed at pH 6 than at pH 8. Figure 13 compares the inactivation of the coliform, f2 and polio virus 1 at pH 6 and pH 8 under the conditions of an approximately 1.0 mg/liter initial free chlorine residual and 1 to 10% added sewage. The difference in inactivation between the two pH levels is particularly evident at 1 and 5% sewage for the coliform, with greater than 3 logs inactivation in two minutes at pH 6 and 1.4 logs inactivation at pH 8 with 1% sewage, and 2.5 logs inactivation at pH 6 and 0.1 log inactivation at pH 8 in two minutes for 5% sewage. For polio virus 1 and f2, 2 logs or greater inactivation was obtained in 2 minutes at pH 6, with less than 1 log inactivation at pH 8, in the presence of 1% sewage. The effect of pH is not as great when starting with a combined chlorine residual, as is shown in Figure 14. Although the degree of difference was smaller with a combined residual, greater inactivation was obtained at pH 6. Figure 15 shows that the same trends were evident when lower chlorine residuals and sewage levels were employed.

Chlorine Residuals

The mean time zero, 2 minute, and 120 minute free and total chlorine residuals accompanying the experimental trials shown in the previous figures are shown in Table 5. Complete chlorine residual data is found in Appendix A. A total chlorine residual was always detected 120 minutes after sewage

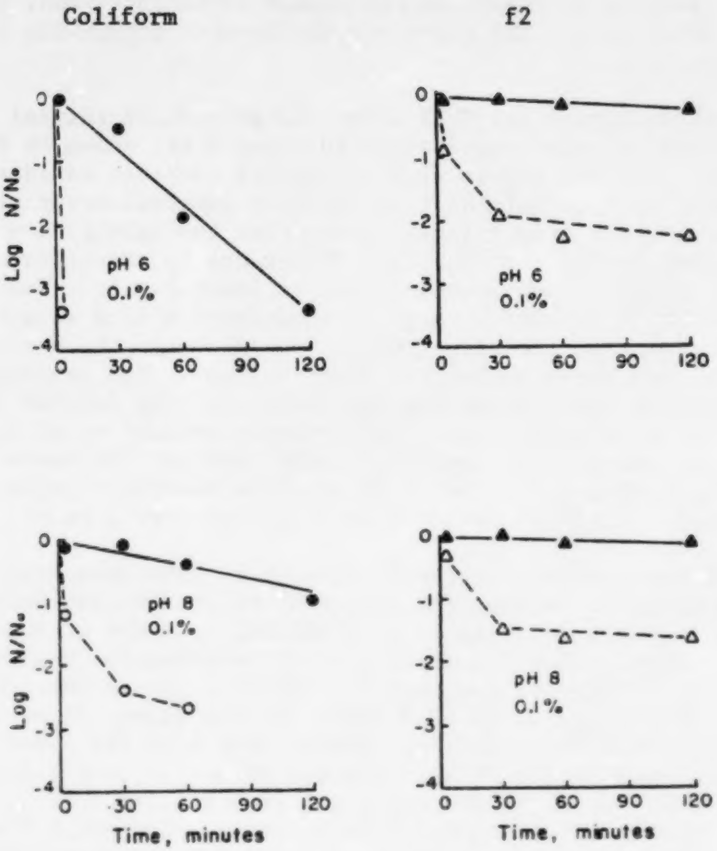

Figure 12. Inactivation of the coliform (○) and f2 (△) in the presence of 0.1% sewage with an approximate initial chlorine residual of 0.3 mg/liter at pH 6.0 and 8.0. Open symbols - initial free chlorine residual, average of 4 trials. Closed symbols - initial combined chlorine residual, average of 5 trials.

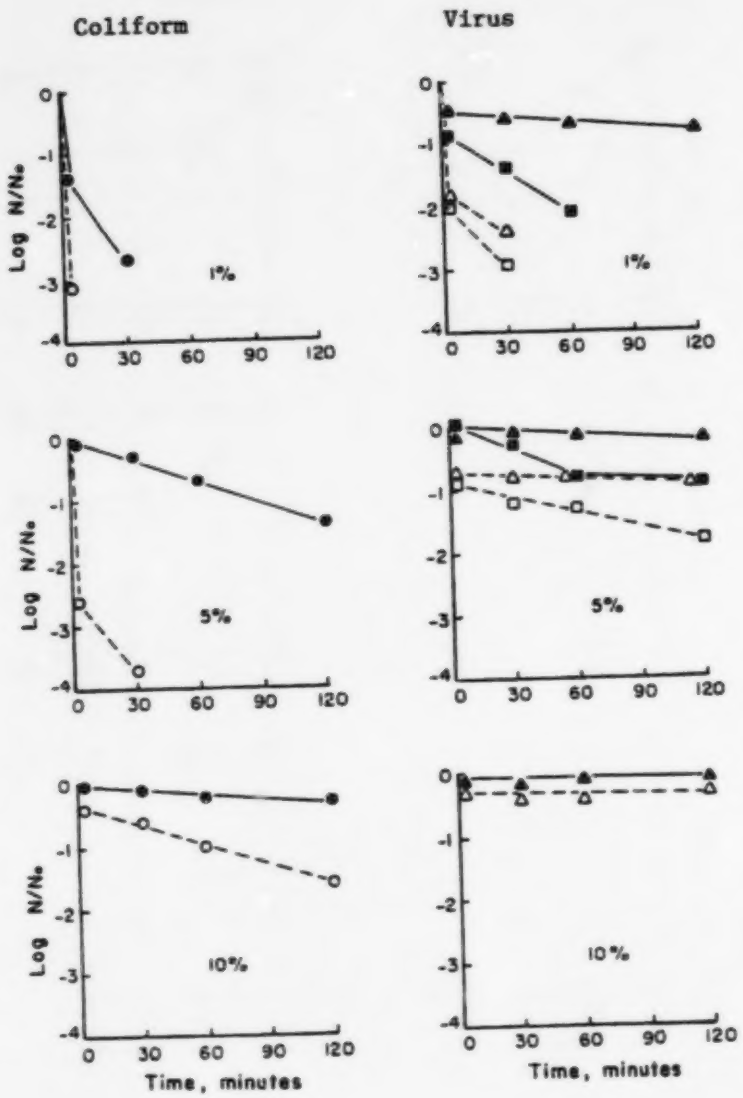

Figure 13. Inactivation of the coliform (○), f2 (△) and poliovirus 1 (□) by an approximate initial free chlorine residual oı 1 mg/liter in the presence of 1 to 10% sewage at pH 6 (open symbols), average of 5 trials and pH 8 (closed symbols), average of 4 trials.

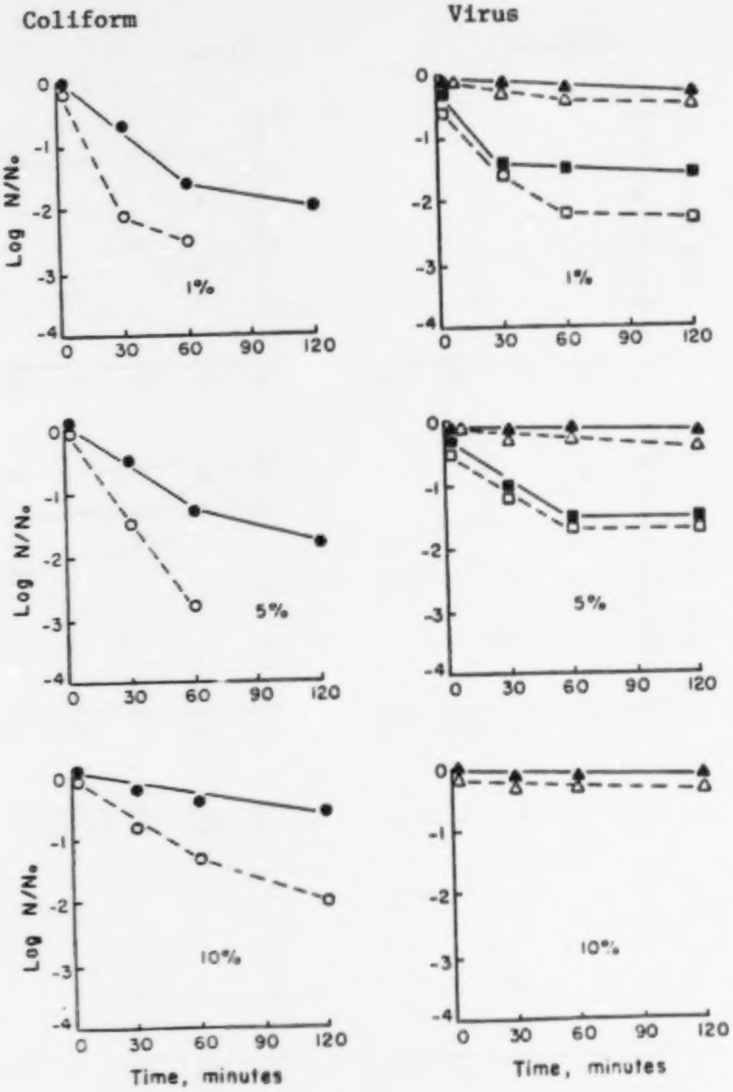

Figure 14. Inactivation of the coliform (○), f2 (△) and poliovirus 1 (□) by approximate initial combined chlorine residual of 1 mg/liter in the presence of 1, 5 and 10% sewage at pH 6 (open symbols), average of 8 trials and pH 8 (closed symbols), average of 7 trials.

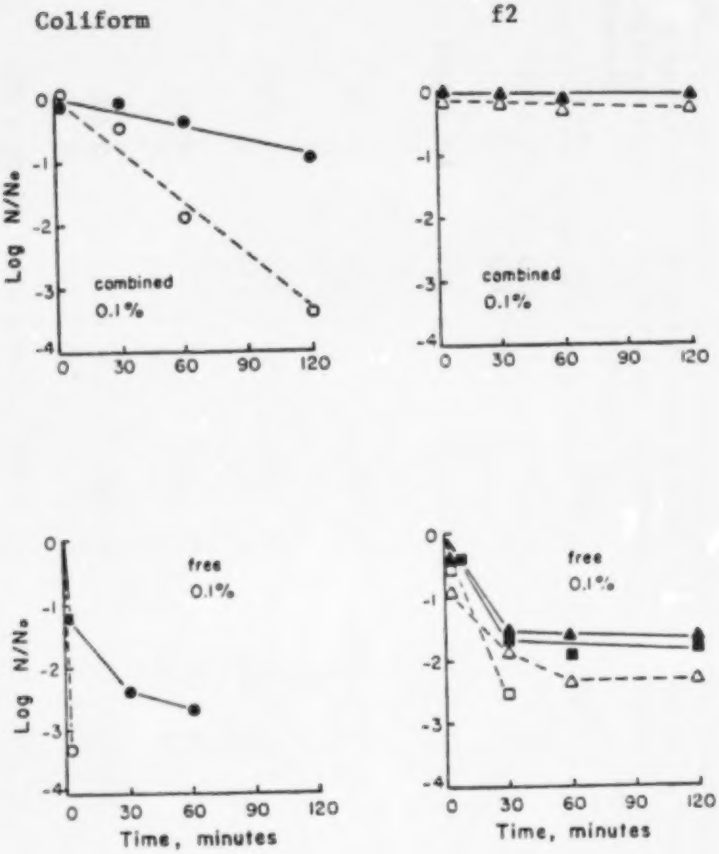

Figure 15. Effect of pH on the inactivation of the coliform (○) f2 (△) and poliovirus 1 (□) by an initial approximately 0.3 mg/liter free or combined chlorine residual in the presence of 0.1% sewage. Open symbols - pH 6.0, average of 4 to 5 trials. Closed symbols - pH 8.0, average of 4 to 5 trials.

TABLE 5. MEAN CHLORINE CONCENTRATIONS AFTER ADDITION OF VARYING AMOUNTS OF SEWAGE AT pH 6 AND 8

pH	% sewage added	Mean initial chlorine concentration (standard deviation) free	Mean initial chlorine concentration (standard deviation) total	2 minute mean chlorine concentration (standard deviation) free	2 minute mean chlorine concentration (standard deviation) total	120 minute mean chlorine concentration (standard deviation) free	120 minute mean chlorine concentration (standard deviation) total
8	1.0	1.02 (.26)	1.22 (.25)	.03 (.01)	.81 (.11)	.01 (.01)	.76 (.11)
	1.0	0	1.07 (.14)	0	.90 (.12)	0	.85 (.12)
	5.0	1.02 (.26)	1.22 (.25)	.01 (.01)	.47 (.11)	0 (.005)	.46 (.11)
	5.0	0	1.07 (.14)	0	.64 (.13)	0	.55 (.16)
	10.0	1.02 (.26)	1.22 (.125)	0 (0)	.28 (.16)	0 (0)	.23 (.16)
	10.0	0	1.07 (.14)	0	.38 (.16)	0	.34 (.17)
6	1.0	1.02 (.23)	1.21 (.24)	.06 (.02)	.83 (.14)	.02 (.02)	.77 (.13)
	1.0	0	1.07 (.14)	0	.97 (.09)	0	.84 (.13)
	5.0	1.02 (.23)	1.21 (.24)	.01 (.01)	.50 (.10)	0 (0)	.41 (.08)
	5.0	0	1.07 (.14)	0	.67 (.14)	0	.53 (.14)
	10.0	1.02 (.23)	1.21 (.24)	0 (0)	.24 (.11)	0 (0)	.16 (.09)
	10.0	0	1.07 (.14)	0	.38 (.21)	0	.27 (.19)
8	0.1	.24 (.02)	.36 (.02)	.04 (.01)	.23 (.01)	.02 (.01)	.21 (.01)
	0.1	0	.31 (.06)	0	.27 (.05)	0	.26 (.06)
6	0.1	.25 (.05)	.36 (.05)	.07 (.03)	.26 (.03)	.04 (.01)	.23 (.05)
	0.1	0	.30 (.06)	0	.29 (.06)	0	.27 (.07)

addition under all of the conditions tested. This total residual was generally in the combined chlorine form, with traces of free chlorine detectable only under conditions of low dosage levels and pH 6. The total chlorine residual was always larger when an initial combined residual, opposed to an initial free residual, was used, even though the mean initial concentration was higher for free chlorine. The difference in the total chlorine residual at 2 and 120 minutes with an initial free or combined residual is shown on a percentage basis in Table 6. This table was constructed by taking the percent of the initial total residual remaining at 2 and 120 minutes for each trial, and then averaging the resulting percentages for each set of conditions. The total chlorine residual at 2 minutes was 11 to 23 percent lower when starting with a free chlorine residual than for an initial combined chlorine residual. Increasing the amount of sewage added resulted in a decrease in the chlorine residual.

Extended Time Studies

The results from the series of experiments where samples were held over an extended time period for monitoring of regrowth or die-away of the coliform organism are shown in Figure 16. Complete data for coliform, *S. typhimurium* and *S. sonnei* are presented in Appendix B. Figure 16 was constructed from data averaged from 66 samples, regardless of pH, temperature, chlorine residual and sewage levels, and shows general trends obtained for all conditions (pH 6 or 8; 0.01 to 10% sewage; 0, 20, 30°C, and 0.2 to 1.0 mg/liter free or combined residual). In 35 out of the 66 samples, inactivation of the coliform organism to the lower sensitivity limit of the assay (-3.8 logs average) occurred within 2 hours. In another 26 samples, the average inactivation after 2 hours contact was 1.8 logs (range 0 to -3.5 logs), with inactivation to the sensitivity limit of the assay occurring within 24 hours. In both cases, no regrowth of the microorganism was observed after reductions to the sensitivity limit had occurred. The remaining 5 samples are representative of the cases where the initial chlorine residual was ineffective against the introduced contaminant. This occurred at the higher sewage levels tested for each range of initial chlorine residuals. The maximum increase in bacterial numbers obtained over the storage period was 0.6 logs, while the greatest decrease was 0.5 logs. Figure 16 also shows the average changes in bacterial numbers over a 7 day period which occurred in the 13 dechlorinated controls accompanying the 66 samples. The maximum increase in bacterial numbers was 1.2 logs, while the greatest decrease was 0.6 logs. Results obtained with the freshly isolated strain of *S. typhimurium* and the laboratory strains of *S. sonnei* were similar to those shown here for the coliform.

RESERVOIR STUDIES

Reservoir studies were originally designed without mixing, in order to simulate the manner in which a contaminant enters a large tank or reservoir in the distribution system. Since it was found that the tank becomes thoroughly mixed by sample withdrawal and refilling, the tanks were mixed after contaminant addition, to insure reproducible conditions.

TABLE 6. CHLORINE RESIDUAL CONCENTRATIONS AFTER SEWAGE ADDITION, AS PERCENT OF INITIAL TOTAL CHLORINE CONCENTRATION

pH	percent added sewage	Mean initial Cl concentration (standard deviation) Free	Total	Total Cl concentration as % of initial concentration (standard deviation) 2 min	120 min
8	1.0	0	1.07 (.14)	84 (6)	79 (6)
	1.0	1.02 (.26)	1.22 (.25)	68 (8)	63 (8)
	5.0	0	1.07 (.14)	60 (10)	51 (14)
	5.0	1.02 (.26)	1.22 (.25)	42 (17)	40 (16)
	10.0	0	1.07 (.14)	37 (16)	32 (16)
	10.0	1.02 (.26)	1.22 (.25)	26 (17)	22 (16)
6	1.0	0	1.07 (.14)	88 (3)	79 (14)
	1.0	1.02 (.23)	1.21 (.24)	69 (3)	64 (3)
	5.0	0	1.07 (.14)	63 (11)	49 (14)
	5.0	1.02 (.23)	1.21 (.24)	43 (11)	35 (9)
	10.0	0	1.07 (.14)	36 (20)	26 (19)
	10.0	1.02 (.23)	1.21 (.24)	22 (12)	15 (10)
8	.10	0	.31 (.06)	88 (1)	83 (5)
	.10	.24 (.02)	.36 (.02)	65 (5)	62 (6)
6	.10	0	.30 (.06)	94 (5)	87 (7)
	.10	.25 (.05)	.36 (.05)	73 (6)	63 (9)

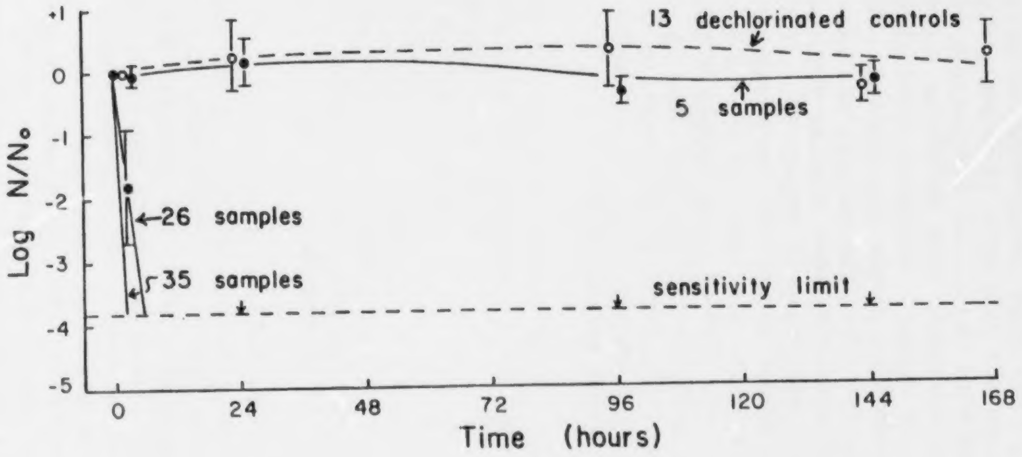

Figure 16. Effect of long term storage on the level of the coliform organism in sewage-tap water mixtures. The bars represent one standard deviation around each point.

The first series of experiments was performed using tap water as the water source. Complete data for this and other runs are found in Appendix C. Figure 17 shows the inactivation curves of coliforms and f2 in the presence of 1, 5 and 10% sewage with an initial 0.38 - 0.52 mg/liter free chlorine residual, (0.85 - 0.93 mg/liter total chlorine) at pH 8.0 to 8.4 and 28-29°C. Biological date were corrected for dilution, so the curves indicate the actual inactivation observed. Table 7 gives the chemical data for this experimental run. Three logs inactivation of coliforms were observed after 120 minutes contact time with 1% sewage, while between 1 and 2 logs removal were observed with the higher percentages of sewage. The bacterial virus, f2 was more resistant than coliforms, with a maximum inactivation of 2 logs with 1% sewage. Chlorine residual data show no free chlorine present after the addition of the contaminant. The total chlorine residual remains fairly constant after the initial decrease caused by the addition of sewage. Results obtained under similar conditions in the holding tank experiments were presented in Figure 10. In the holding tank studies the contaminant was seeded autoclaved raw sewage instead of the raw sewage with natural coliform populations used in the reservoir studies. The studies also differed in the fact that the sample withdrawn was replaced with fresh water containing chlorine in reservoir studies, but not in holding tank studies. Greater inactivation was observed in the reservoir studies at higher sewage levels, while greater inactivation was observed in the holding tank studies at lower sewage levels.

Figure 18 shows the inactivation curves of coliforms and f2 in the presence of 1, 5 and 10% sewage (initially) with an initial combined chlorine residual of 1.5 mg/liter at pH 8.2 - 8.4 and 28-30°C. Table 8 gives the accompanying chemical data. Greater than 3 logs reduction of coliform were observed after 2 hours contact time, even with 10% sewage present. While the inactivation of f2 was slower, 3 logs reduction did occur in the presence of 1% sewage. The inactivation curves obtained in the holding tank studies under similar conditions are given in Figure 10. The magnitudes of the reduction in coliform and f2 were greater in the reservoir system.

Figure 19 shows the inactivation curves obtained in the presence of 1% sewage with an initial combined chlorine residual in tap and river water at 27-29°C. The pH was adjusted to 8.0 in all experiments and the effect of the different water sources was observed. The chemical data are given in Table 9. The inactivation of f2 was greater in tap water than in the 1:1 mix of tap and river water or in river water. Greater than 2.5 logs inactivation of f2 occurred in the tap water after 120 minutes contact, while less than 1 log removal was observed with river water present. The degree of difference in the inactivation of coliforms with the different water sources was less than for f2, but they generally followed the same trend. The inactivation was greatest in tap water and least in river water, with a 1:1 mix yielding an intermediate result.

MUNICIPAL DISTRIBUTION SYSTEMS

Microbiological Aspects

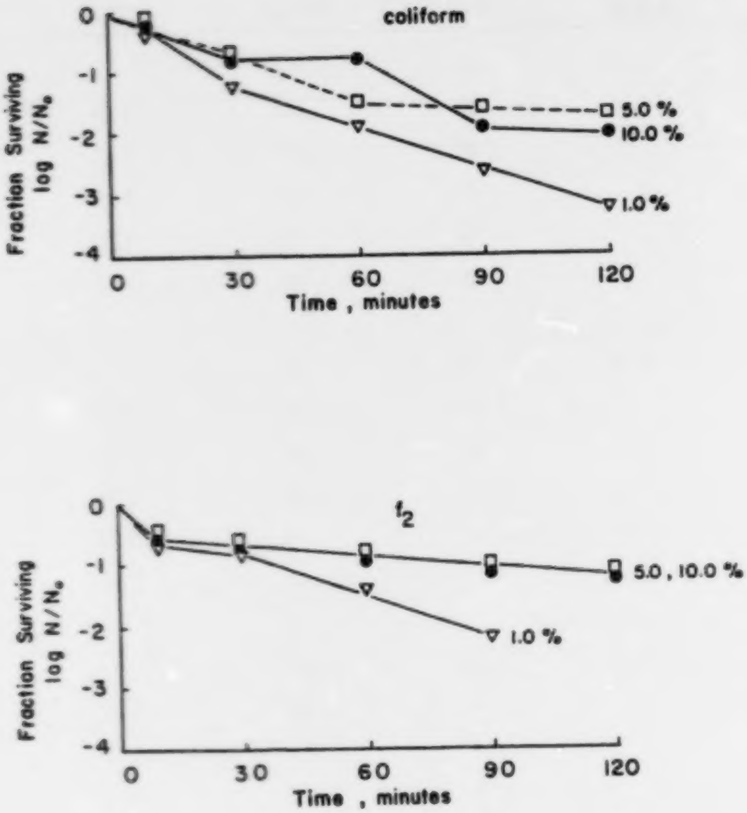

Figure 17. Inactivation of natural populations of coliforms and seeded f2 virus contained in sewage after addition to tap water in the reservoir with 0.38 to 0.52 mg/liter free chlorine (0.85-0.93 mg/liter total chlorine) at pH 8.0 to 8.4, 28-29°C. The precent sewage was added as indicated.

TABLE 7. CHEMICAL DATA AFTER THE ADDITION OF RAW SEWAGE TO TAP WATER FROM THE FT. MEADE, MARYLAND WATER DISTRIBUTION SYSTEM WITH FREE CHLORINE AT 28-29°C

Sample Time	% Sewage Added	Chlorine Residual, mg/l Free	Chlorine Residual, mg/l Total	Turbidity NTU	pH
0	1.0	.41	.85		8.2
10		0	.62	2.5	8.4
30		0	.67	1.5	8.4
60		0	.67	1.5	8.4
90		0	.72	1.5	8.4
120		0	.70	1.2	8.3
0	5.0	.38	.74		8.2
10		0	.35	3.3	8.1
30		0	.37	3.4	8.2
60		0	.48	2.9	8.2
90		0	.74	2.5	8.1
120		0	.62	2.0	8.2
0	10.0	.52	.93		8.2
10		0	.14	5.3	8.1
30		0	.21	5.1	8.0
60		0	.39	4.2	8.1
90		0	.49	3.1	8.1
120		0	.55	2.8	8.1

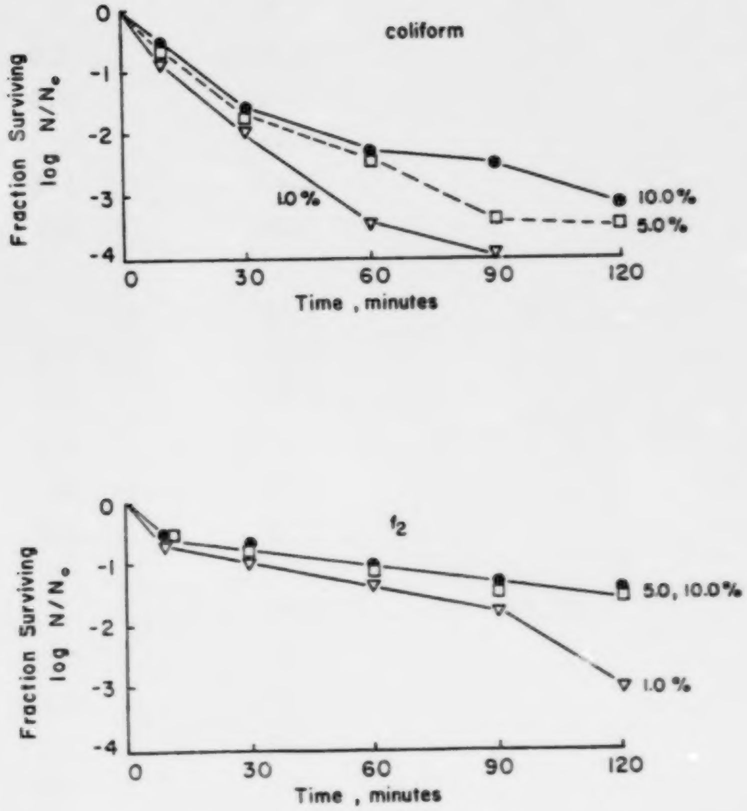

Figure 18. Inactivation of natural populations of coliforms and seeded f2 virus contained in sewage after addition to tap water in the reservoir with 1.50 mg/liter combined chlorine at pH 8.2-8.4, 28-30°C. The percent sewage was added as indicated.

TABLE 8. CHEMICAL DATA AFTER THE ADDITION OF RAW SEWAGE TO TAP WATER FROM THE FT. MEADE, MARYLAND WATER DISTRIBUTION SYSTEM WITH COMBINED CHLORINE AT 28-30°C

Sample Time, min.	% Sewage Added	Total Chlorine residual, mg/l	Turbidity NTU	pH
0	1.0	1.50		8.2
10		1.30	2.0	8.3
30		1.44	2.0	8.4
60		1.44	1.3	8.4
90		1.43	1.1	8.3
120		1.36	1.1	8.3
0	5.0	1.52		8.3
10		1.00	3.4	8.2
30		1.09	3.1	8.2
60		1.13	2.3	8.2
90		1.34	1.9	8.2
120		1.30	1.7	8.2
0	10.0	1.50		8.3
10		.65	5.2	8.2
30		.70	4.8	8.2
60		.74	3.5	8.2
90		.92	3.0	8.2
120		.95	2.5	8.2

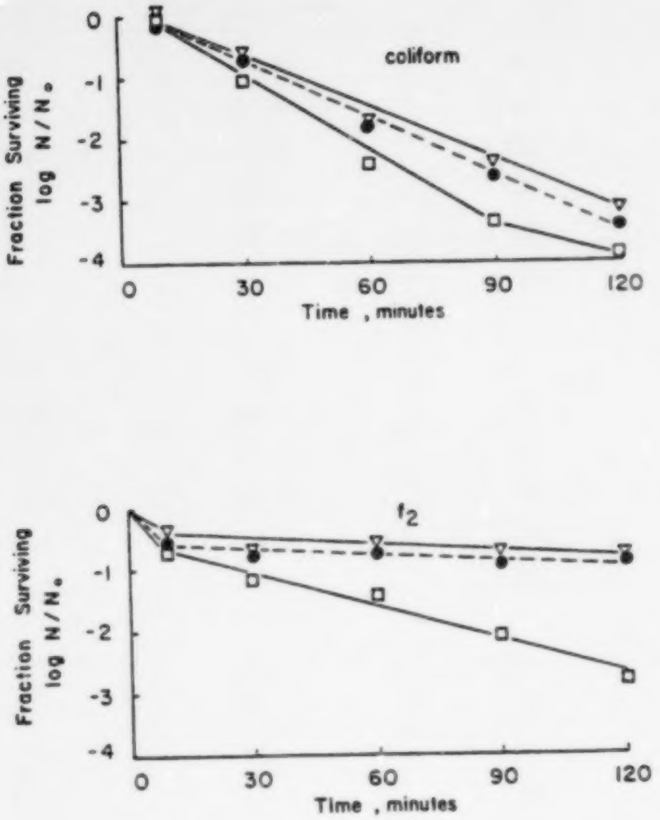

Figure 19. Inactivation of natural populations of coliforms and seeded f2 virus contained in sewage after addition to tap water (□), 1:1 tap and river mixture (●), and river water (▽) in the reservoir with 1.2-1.3 mg/liter combined chlorine at pH 8.0, 27-29°C.

TABLE 9. CHEMICAL DATA AFTER THE ADDITION OF 1% RAW SEWAGE TO TAP WATER, A 1:1 MIXTURE OF TAP AND RIVER WATER, AND RIVER WATER WITH COMBINED CHLORINE AT 27-29°C

Water Source	Sample Time, min.	Total chlorine residual, mg/l	Turbidity NTU	pH
Tap	0	1.30	.80	
	10	1.20	1.1	8.1
	30	1.22	1.3	8.1
	60	1.21	1.6	8.1
	90	1.21	.74	8.1
	120	1.21	.72	8.1
Tap and River 1:1 mixture	0	1.22	4.7	
	10	1.10	3.6	8.0
	30	1.10	4.5	8.0
	60	1.11	3.7	8.0
	90	1.11	4.1	8.0
	120	1.09	4.0	8.0
River	0	1.18	7.0	
	10	.98	5.4	8.0
	30	.98	6.5	8.0
	60	1.03	7.8	8.0
	90	1.00	7.0	8.0
	120	.98	7.3	8.0

Coliforms--

Approximately 850 samples from the Baltimore system were examined for the presence and level of the coliform group. Only 6 positive samples were obtained with MPN/100 values of 2.0 (4 samples) 6.0 and 33.0. Typical colonies from EMB plates for 3 of the positive samples were tested for indole, methyl red, Voges-Proskauer and Simmons citrate. Thirty colonies were tested for each sample. All isolates from 2 of the samples gave - + - + IMVIC patterns while all of the 30 isolates from the remaining sample tested were IMVIC - + + +. Because of the small number of positive samples, no computations of correlations were attempted between coliform level and the physical and chemical parameters of the samples.

Of the 136 samples examined from the Frederick distribution system, 4 were positive for coliforms, with MPN/100 values of $\geq$ 2,400, 2.0, 49 and 170. All 4 of these samples came from the same sample station and represented 12% of the samples taken from this station. Isolates from 3 of the positive samples were tested for their IMVIC pattern. For one sample, all isolates were - - + +, while another sample gave all - + - +. Isolates from the third sample showed a varied IMVIC pattern, with 13, - + - +; 12, - + + +; 7, - + - -; and 2, + + - -.

Plate Count--

The effect of incubation time on the number of bacterial colonies found on the standard plate count agar is shown in Figure 20. The results are plotted as N/N_f X 100, where N is the number of colonies at any time t, and N_f is the number of colonies on the terminal day. Thus the scale N/N_f X 100 is the percentage of the final count. For the 35°C data, each point is the mean value of 37 samples, while for the 20°C data, each point is the mean value of 35 samples. Bars represent one standard deviation around the mean. The 35°C plate count increased with time up to 6 days (144 hours) incubation before leveling off. The 20°C plate count increased over the 14 day period monitored. Plates were routinely counted at 48 hours and 96 hours incubation at 35°C. The 48 hour time was selected to conform with standard practice (Standard Methods, 1975) while the 96 hour time was found to give maximum colony development without overcrowding. It was necessary to avoid overcrowding, since colonies were picked from the plates for subsequent biochemical screening. The 96 hour count represented approximately 65% of the final count, as seen in Figure 20. The 9 day incubation for the 20°C plates was also selected to avoid overcrowding and also represented approximately 65% of the final count. Complete plate count data are found in Appendix D.

Linear Regression Analysis of Distribution System Data--

Samples were collected weekly for 42 weeks (July 17, 1977 - May 31, 1978) from the Baltimore distribution system and for 35 weeks (July 24, 1977 - April 12, 1978) from the Frederick distribution system. The basic data for temperature, turbidity, chlorine residual, pH, coliform, 35°C plate count after 48 and 96 hours incubation, and 20°C plate count after 9 days incubation for each sample station are given, by week of sampling, in Appendix D.

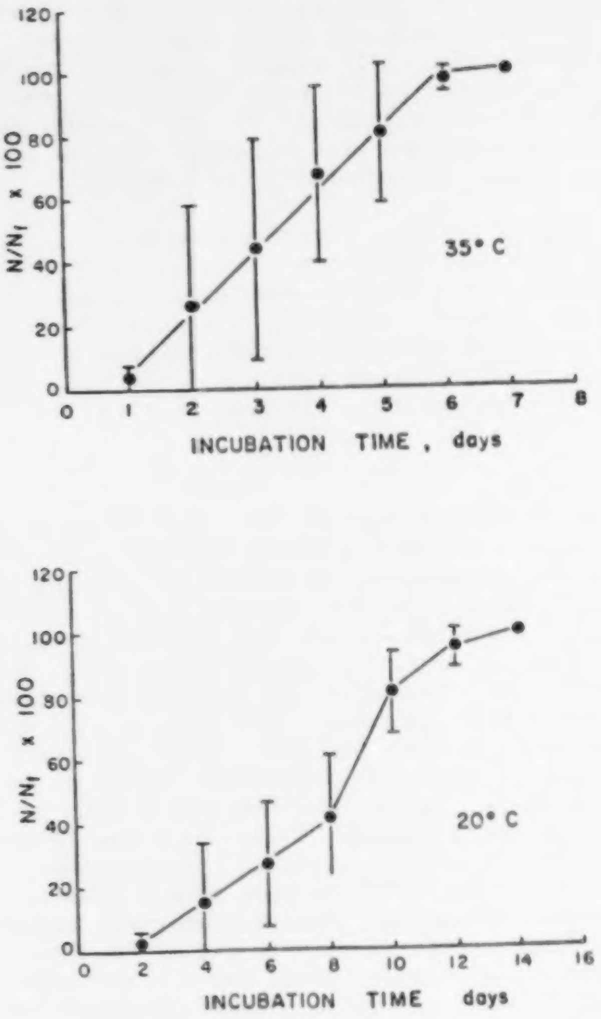

Figure 20. Effect of incubation time on the number of bacterial colonies obtained on standard plate count agar at 20°C and 35°C. Each point represents the mean of 35 to 37 samples, while the bars represent 1 standard deviation around the mean.

Since the Baltimore and Frederick system differ in the type of treatment and kind of chlorine residual maintained, data from the two systems were analyzed separately. Most of the data obtained pertained to the Baltimore system. This information from the Baltimore system was entered into a computer and a linear regression model was utilized. The statistical package for the social sciences (SPSS) (Nie *et al.*, 1975) was used. The variables entered were pH; temperature; turbidity; free chlorine concentration; 35°C, 4 day incubation plate count (PC 4); and 20°C, 9 day incubation plate count (PC 9). Positive coliform was obtained on only 6 of 850 samples and was not included in this analysis. The 35°C, 48 hour, plate count data were also not included in the analysis since 93% (742 of 798) of the samples had plate counts of less than 30/ml, and 86% showed plate counts of less than 10/ml. For simplicity, cases where one of the above variables was missing were omitted from subsequent analysis, resulting in a total number of 812 cases. The correlation coefficient matrix generated for these variables is shown in Table 10. The values for the two plate counts were transformed into logs before analysis. All subsequent plate count data were given in the form of log plate count. Plate count results were considered the dependent variables while the physical and chemical parameters were considered independant variables. As shown in Table 10, significant correlation ($R \neq 0$, $P = 0.001$) was found for PC 4 and PC 9 versus free chlorine concentration ($R = -0.50$ and $R = -0.66$, respectively), and PC 4 and PC 9 versus turbidity ($R = 0.34$ and $R = 0.29$, respectively). Significant correlation was also obtained for PC 4 versus PC 9 ($R = 0.76$), chlorine concentration versus turbidity ($R = -0.22$) and for chlorine concentration versus temperature ($R = -0.23$).

In order to visualize the relationship of plate count with chemical and physical parameters, scatter plots were constructed. Figures 21 and 22 are plots of all the log plate count values (PC 4 and PC 9) versus the free chlorine residuals in mg/liter. The numbers plotted on these and subsequent figures represent instances where more than one point occurs at a given log plate count and chlorine residual value, while the stars represent individual points. In these cases, the numbers are the number of points occurring at a particular X and Y value. As would be expected from the values of the correlation coefficients, considerable scatter around the regression line was observed. The equation for the regression line shown in Figure 21 is:

$$\log PC\ 4 = -1.06\ (\text{chlorine residual}) + 1.25 \qquad (1)$$

while the equation of the regression line for PC 9 shown in Figure 22 is:

$$\log PC\ 9 = -1.67\ (\text{chlorine residual}) + 1.84 \qquad (2)$$

The 20°C, 9 day incubation plate count is more sensitive to chlorine residuals than the 35°C, 4 day incubation plate count, as shown by the larger negative slope in equation (2) above.

Scattergrams of log PC 4 and log PC 9 versus turbidity in NTU are shown in Figures 23 and 24. The slopes of these two lines are 0.47 for PC 4 and 0.66 for PC 9. Although the data are more widely scattered than in the case of plate count versus chlorine residual, a significant positive

TABLE 10. CORRELATION COEFFICIENT MATRIX FOR CHEMICAL, PHYSICAL AND BIOLOGICAL DATA COLLECTED IN THE BALTIMORE WATER DISTRIBUTION SYSTEM

```
CORRELATION COEFFICIENT COMPUTATION

- - - - - - - - - - - - P E A R S O N   C O R R E L A T I O N   C O E F F I C I E N T S -

              PH         TEMP       TURBID     FREECL     LOGPC4     LOGPC9

PH          1.0000      0.0431     0.0017    -0.0593     0.0045    -0.0096
           (    0)     (  812)    (  812)    (  812)    (  812)    (  812)
           S=0.001     S=0.110    S=0.481    S=0.046    S=0.449    S=0.392

TEMP        0.0431      1.0000    -0.0030    -0.2329     0.2759     0.1915
           (  812)     (    0)    (  812)    (  812)    (  812)    (  812)
           S=0.110     S=0.001    S=0.466    S=0.001    S=0.001    S=0.001

TURBID      0.0017     -0.0030     1.0000    -0.2178     0.3387     0.2934
           (  812)     (  812)    (    0)    (  812)    (  812)    (  812)
           S=0.481     S=0.466    S=0.001    S=0.001    S=0.001    S=0.001

FREECL     -0.0593     -0.2329    -0.2178     1.0000    -0.4968    -0.6623
           (  812)     (  812)    (  812)    (    0)    (  812)    (  812)
           S=0.046     S=0.001    S=0.001    S=0.001    S=0.001    S=0.001

LOGPC4      0.0045      0.2759     0.3387    -0.4968     1.0000     0.7588
           (  812)     (  812)    (  812)    (  812)    (    0)    (  812)
           S=0.449     S=0.001    S=0.001    S=0.001    S=0.001    S=0.001

LOGPC9     -0.0096      0.1915     0.2934    -0.6623     0.7588     1.0000
           (  812)     (  812)    (  812)    (  812)    (  812)    (    0)
           S=0.392     S=0.001    S=0.001    S=0.001    S=0.001    S=0.001

(COEFFICIENT / (CASES) / SIGNIFICANCE)
```

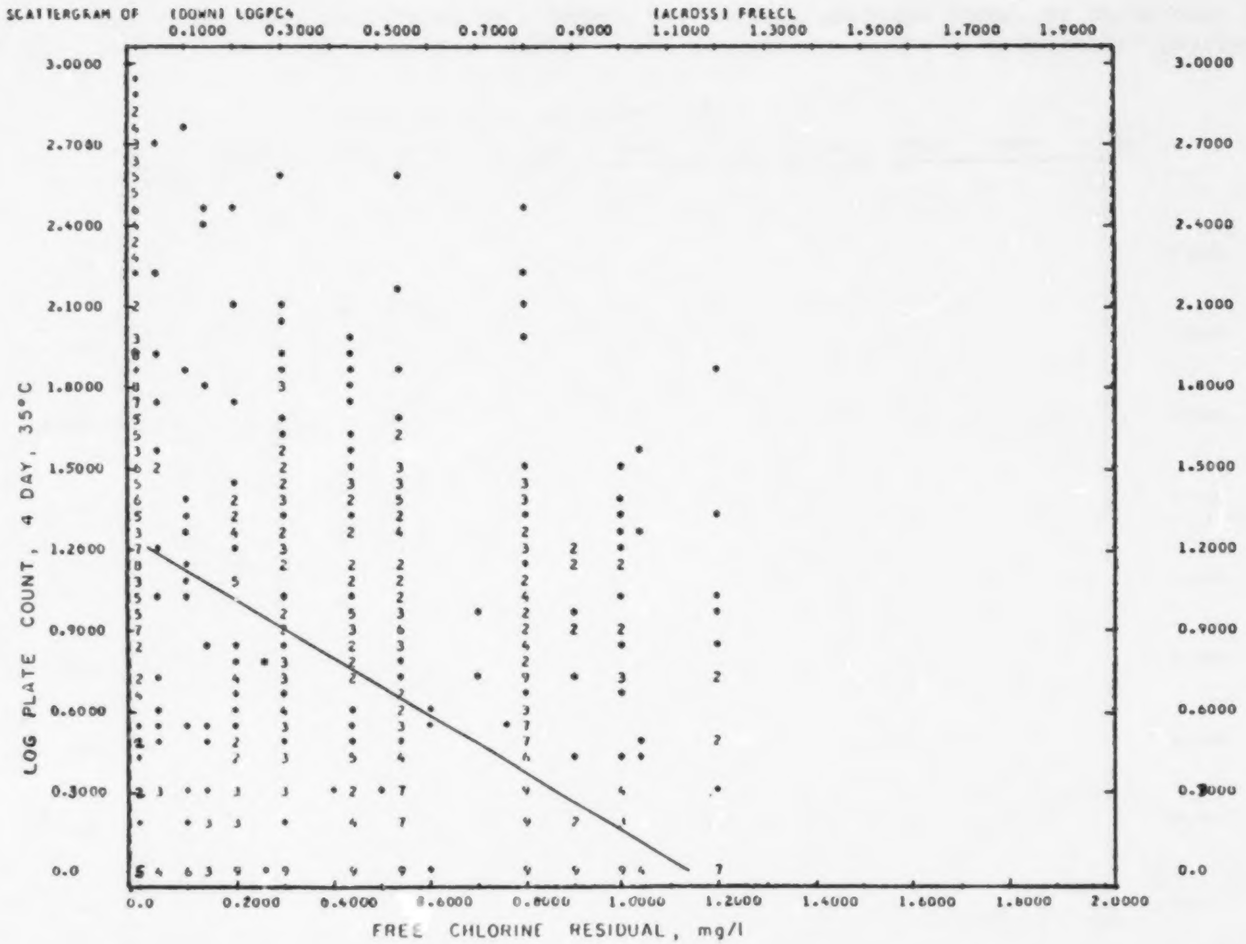

Figure 21. Scattergram - Log 35°C plate count, 4 day incubation versus free chlorine, Baltimore. Stars represent individual data points and numbers indicate number of coincident data points.

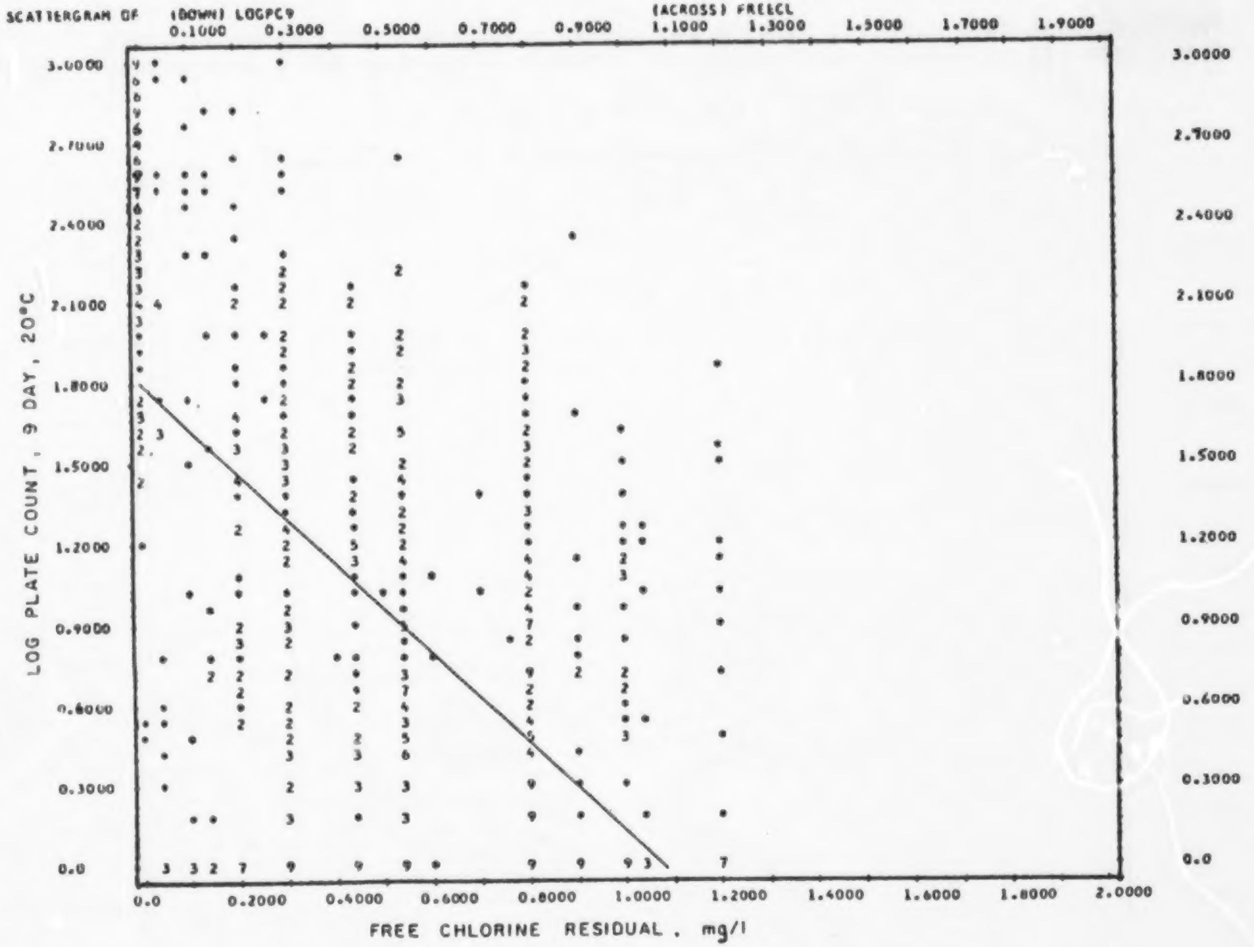

Figure 22. Scattergram - Log 20°C plate count, 9 day incubation versus free chlorine, Baltimore. Stars represent individual data points and numbers indicate number of coincident data points.

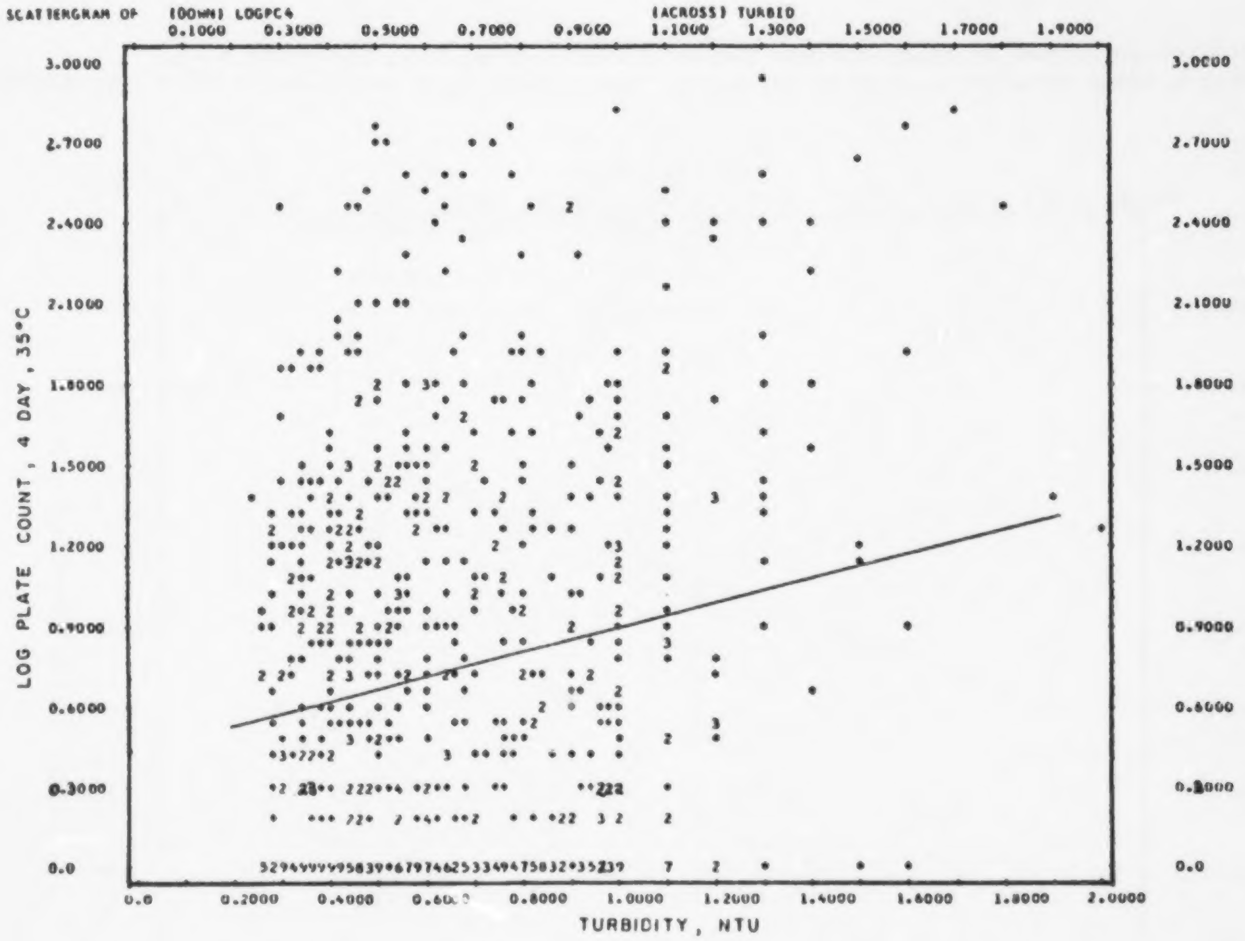

Figure 23. Scattergram - Log 35°C plate count, 4 day incubation versus turbidity, Baltimore. Stars represent individual data points and numbers indicate number of coincident data points.

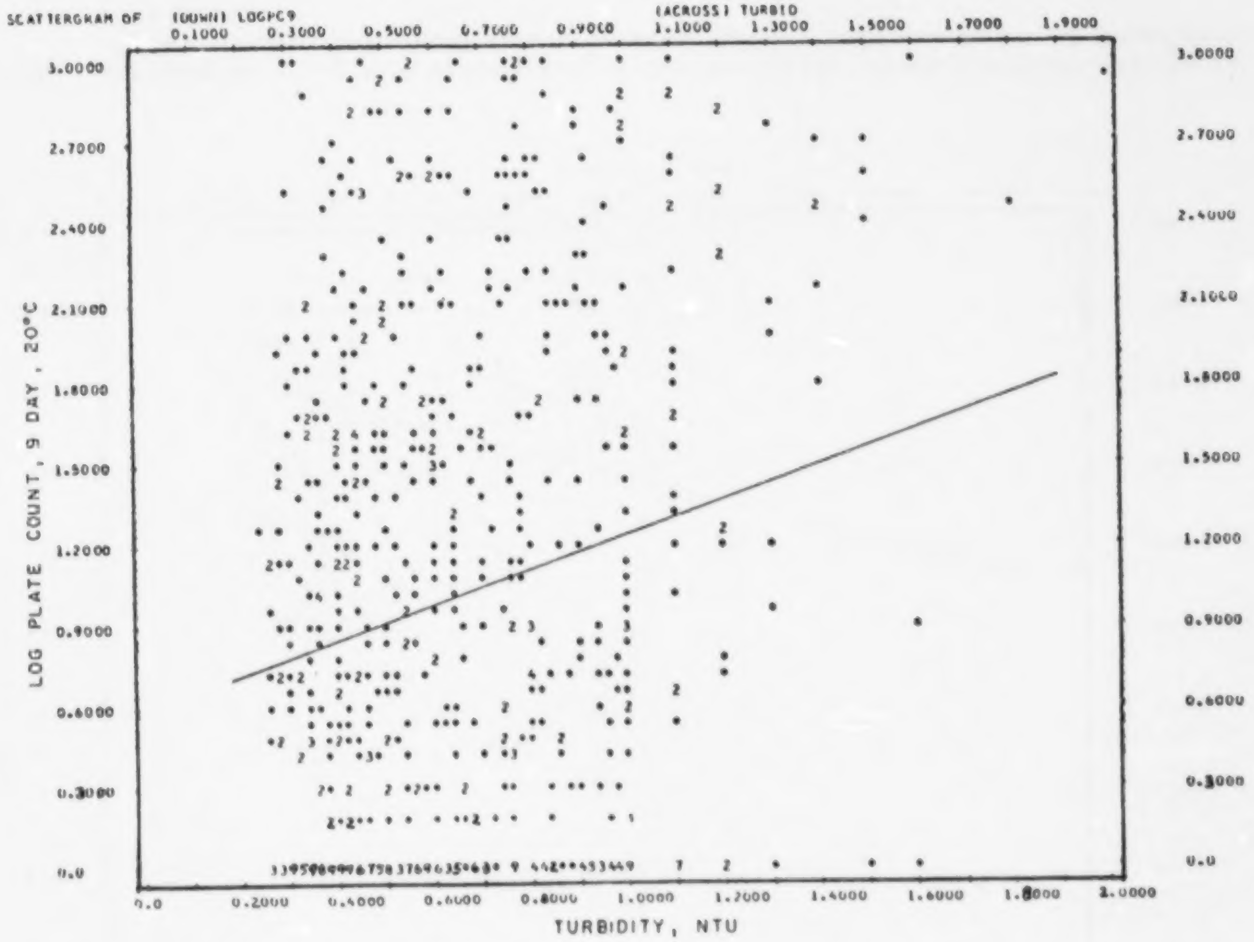

Figure 24. Scattergram - Log 20°C plate count, 9 day incubation versus turbidity, Baltimore. Stars represent individual data points and numbers indicate number of coincident data points.

relationship was observed. It should be noted that a fairly narrow range of turbidities was encountered in this study. Most of the samples taken had turbidities of less than 1.2 NTU.

Figure 25 shows the relationship of free chlorine level and turbidity. This figure was constructed to look for interaction between these two independant variables. The correlation was found to be significant, but the slope of -0.17 indicates that the changes in turbidity per unit change (1 mg/liter) of chlorine residual is small.

The greatest correlation (R = 0.76) of any of the variables was obtained for PC 4 versus PC 9 as shown in the scattergram in Figure 26. The 20°C, 9 day incubation plate count consistently gave higher levels of bacteria than the 35°C, 4 day incubation, as shown by the distribution of points to the right of the diagonal in Figure 26.

It is apparent from previous figures that, although a linear regression analysis does show correlation between turbidity, chlorine residuals, or temperature versus plate counts, the use of one of the physical or chemical parameters as a predictor of individual plate count values will fail because of the wide scatter of the data.

In order to test the utility of the parameters in predicting mean plate count values, log plate count data were grouped by ranges of chlorine residuals and turbidities and the mean log plate count within each range was calculated. The ranges used were in increments of 0.1 mg/liter for chlorine and 0.1 NTU for turbidity. The resulting mean plate count was plotted against the midpoint of the range. Equations for the regression curves were calculated, using SPSS. The curves for PC 4 and PC 9 versus chlorine residual are shown in Figures 27 and 28. Larger correlation coefficients were obtained for the mean plate count values shown in these figures than for the individual values shown in the previous scattergrams. The value of R for mean log PC 4 versus midpoint of chlorine concentration was -0.62, while the value for log PC 9 was -0.73.

The results shown in Figures 27 and 28 indicate that a linear model is perhaps not the best choice for chlorine residual since the decrease in log plate count seems almost exponential. This is due in large part, to the dramatic decrease in log plate count between the chlorine ranges of 0-0.1 and 0.1-0.2 mg/liter. Many of the samples from Baltimore that fell within the range 0-0.1 mgCl/l had no measurable chlorine residual. This shows that any measurable chlorine residual at all is effective in reducing the plate count. This effect is more clearly shown in Tables 11 and 12. These tables summarize the ranges of plate count values at varying levels of free chlorine. For the 20°C, 9 day incubation plate count, 90% of the samples with chlorine residuals less than 0.04 mg/liter showed plate counts greater than 100 bacteria/ml. Of the samples with chlorine residuals of 0.05 mg/l or greater, no more than 31% gave plate count values greater than 100 bacteria/ml. While the 35°C, 4 day incubation plate counts generally had lower levels of bacteria, the effect of chlorine residual was still apparent. Of the samples with chlorine residuals less than 0.04 mg/liter, 31% gave plate counts greater than 100 bacteria/ml. For samples with chlorine

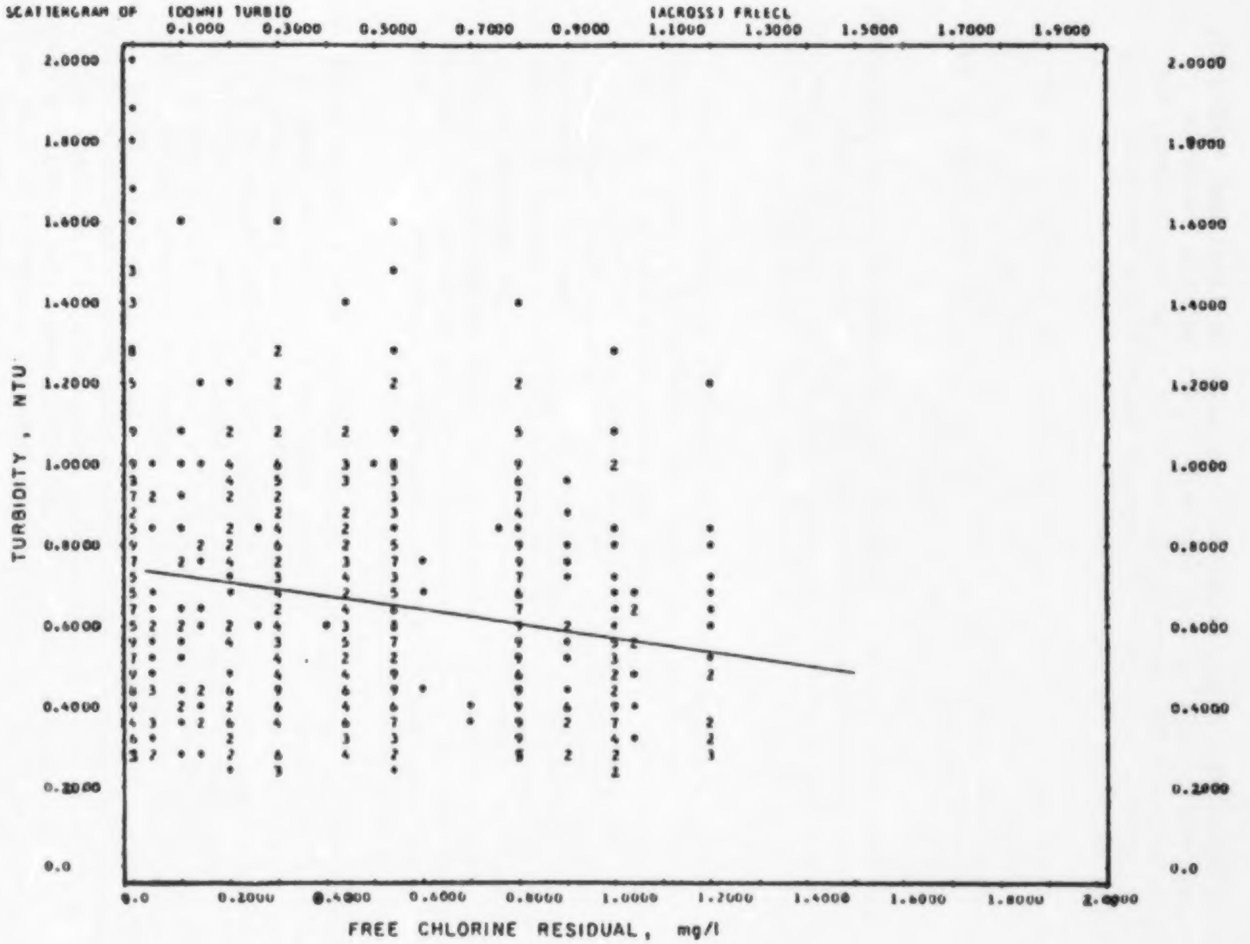

Figure 25. Scattergarm - Turbidity versus free chlorine, Baltimore. Stars indicate individual data points and numbers indicate number of coincident data points.

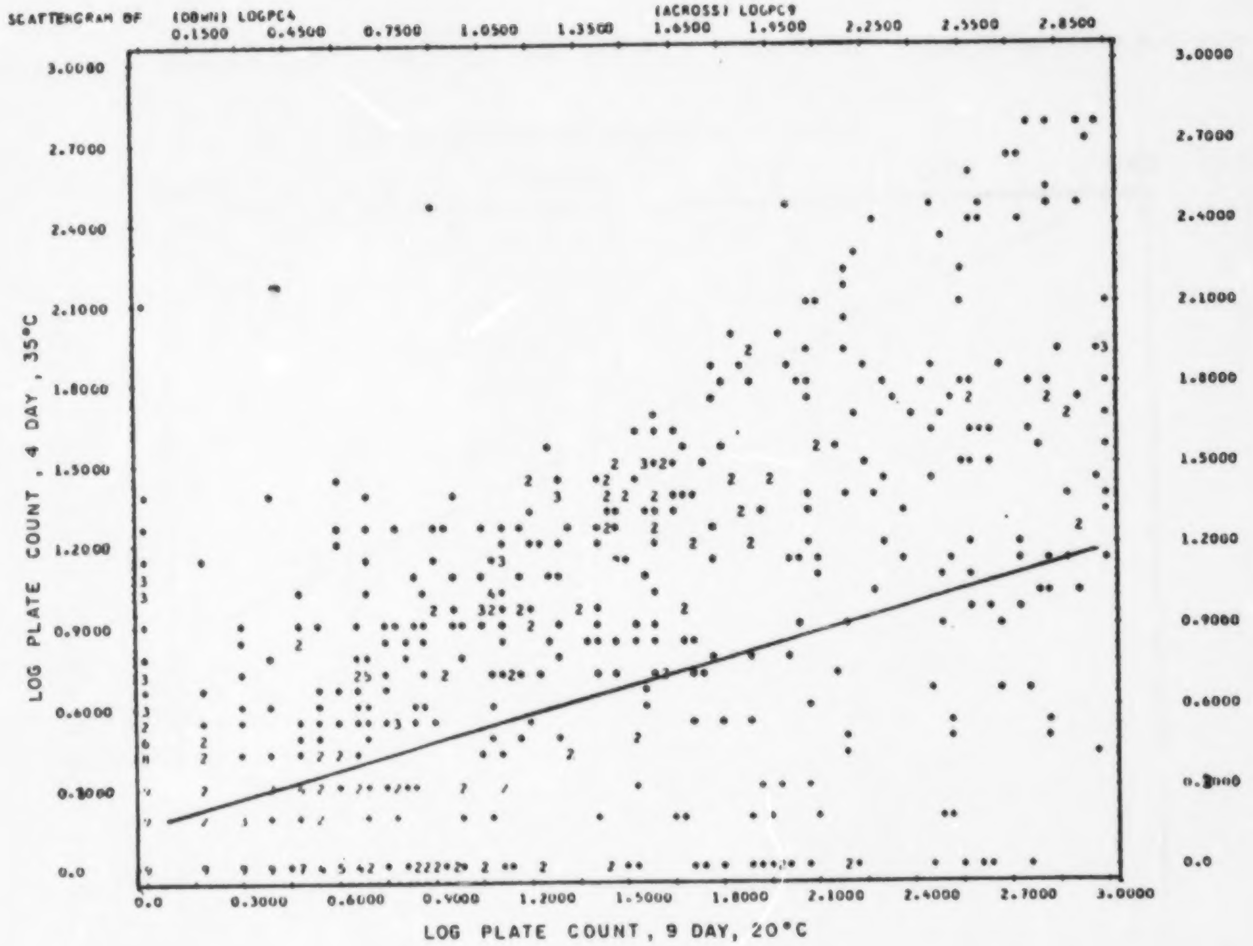

Figure 26. Scattergram - Log 35°C plate count, 4 day incubation versus log 20°C plate count, 9 day incubation, Baltimore. Stars indicate individual data points and numbers indicate number of coincident data points.

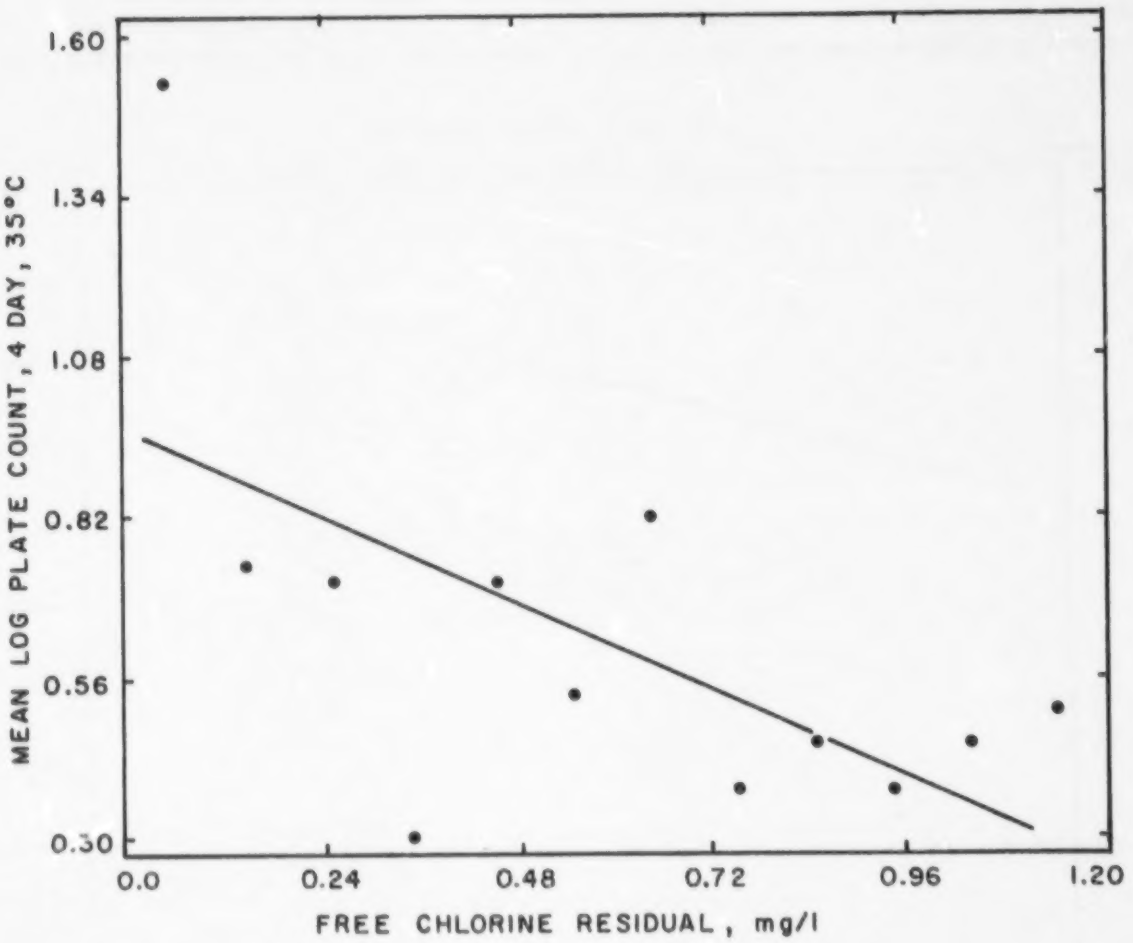

Figure 27. Relationship between the mean log 35°C plate count, 4 day incubation and free chlorine residual, Baltimore.

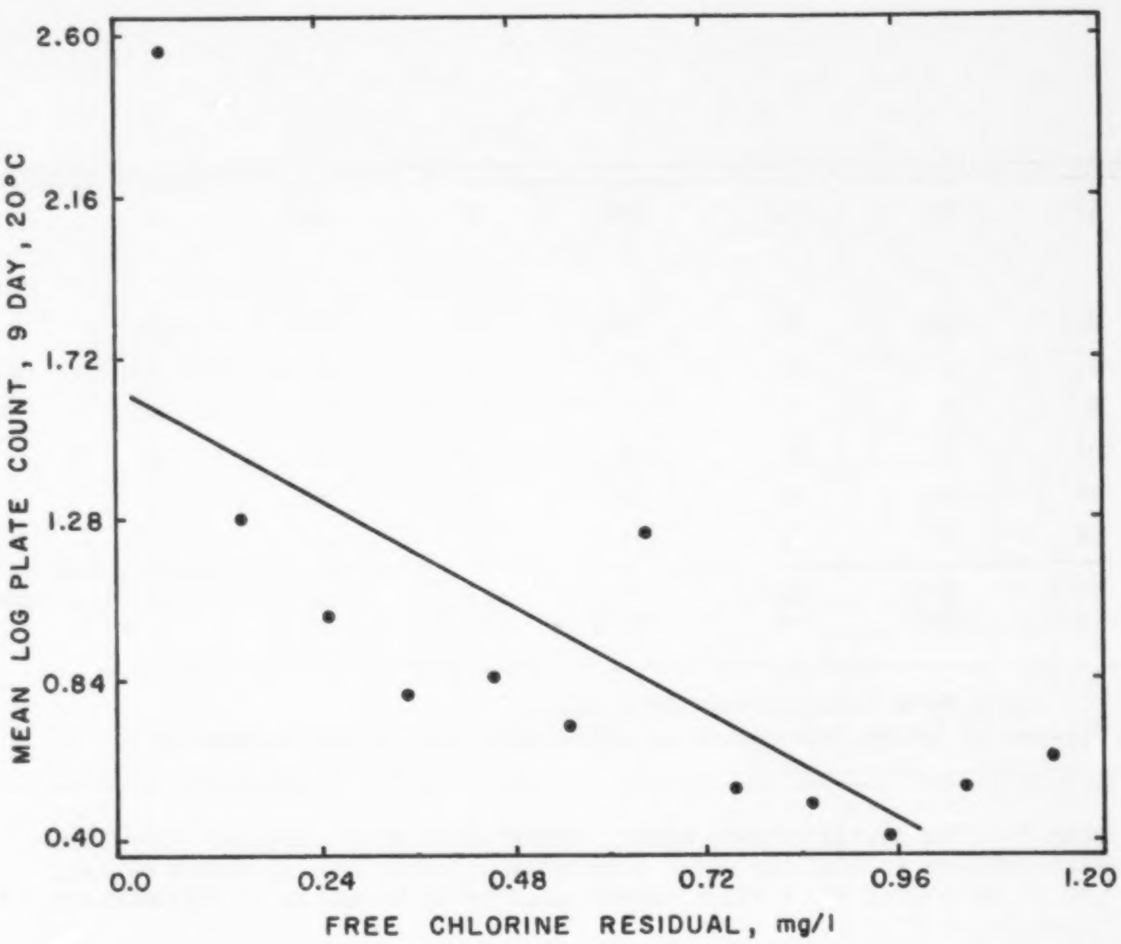

Figure 28. Relationship between the mean log 20°C plate count, 9 day incubation and free chlorine residual, Baltimore.

TABLE 11. DISTRIBUTION OF RANGES OF PLATE COUNT VALUES AFTER 4 DAY INCUBATION AT 35°C FOR VARYING RANGES OF FREE CHLORINE RESIDUALS. DATA ARE FROM 21 SAMPLING SITES IN THE BALTIMORE, MARYLAND WATER DISTRIBUTION SYSTEM SAMPLED WEEKLY FOR A 42 WEEK PERIOD

	% of samples within indicated ranges of plate count values at varying ranges of free chlorine residuals in mg/liter.							
Plate Count colonies/ml	0.00-0.04	0.05-0.20	0.21-0.40	0.41-0.60	0.61-0.80	0.81-1.00	1.01-1.20	All Cl Residuals
<1.0	0.6	9	15	13	21	21	20	13
1-10	19	52	52	61	67	60	60	51
11-100	49	30	27	25	9	19	20	27
101-1000	26	8	4	1	2	0	0	8
1001-10000	5	1	1	0	0	0	0	1
Total %	99.6	100	99	100	99	100	100	100
Total # samples	174	102	92	189	174	68	25	824

TABLE 12. DISTRIBUTION OF RANGES OF PLATE COUNT VALUES AFTER 9 DAY INCUBATION AT 20°C FOR VARYING RANGES OF FREE CHLORINE RESIDUALS. DATA ARE FROM 21 SAMPLING SITES IN THE BALTIMORE, MARYLAND WATER DISTRIBUTION SYSTEM SAMPLED WEEKLY FOR A 42 WEEK PERIOD

	% of samples within indicated ranges of plate count values at varying ranges of free chlorine residuals in mg/liter.							
Plate Count colonies/ml	0.00-0.04	0.05-0.20	0.21-0.40	0.41-0.60	0.61-0.81	0.81-1.00	1.01-1.20	All Cl Residuals
<1.00	0	6	11	9	22	33	22	12
1-10	1	33	38	54	57	48	39	38
11-100	9	29	37	33	19	18	39	24
101-1000	55	27	13	3	2	1	0	18
1001-10000	35	4	1	0.5	0	0	0	8
Total %	100	99	100	99.5	100	100	100	100
Total # Samples	171	102	90	188	175	67	18	811

residuals greater than 0.05 mg/liter, no more than 9% gave plate counts greater than 100 bacteria/ml.

The mean log plate count was plotted against midpoints of the ranges of turbidities in Figures 29 and 30. It was apparent that, even over a relatively narrow range of turbidities, increasing turbidity was associated with an increase in the plate counts. The R value for PC 4 was 0.73, while the R value for PC 9 was 0.88.

In the analysis of data a multiple linear regression program (SPSS) was used to evaluate the relative importance of the independent variables: chlorine residual, turbidity, and temperature in determining log PC 4 or log PC 9. Independent variables were divided into ranges: chlorine residual in increments of 0.1 mg/liter from 0 to 1.2 mg/liter, turbidity values in increments of 0.1 NTU from 0 to 1.3 NTU, and temperature in increments of 2.5°C from 0 to 30°C, and midpoints of the ranges of chlorine residual, turbidity and temperature were used. Dependent variables log PC 4 and log PC 9 were then grouped for each range of chlorine residual, turbidity and temperature values. Thus, for example a group of plate count values was associated with a chlorine residual midpoint of 0.15 mg/liter, a turbidity midpoint of 0.15 NTU, and a temperature midpoint of 1.25°C. All possible regressions were run including 1, 2, or 3 of the independent variables in varying orders. Results given in Table 13 show the independent variables ranked in decreasing order of importance for the 35°C plate count. Two methods were used to rank the independent variables, the change in R square accompanying the introduction of the variable into the equation (Draper & Smith, 1966) and the use of standardized regression coefficients (Nie *et al.*, 1975). Table 13 indicates that the R square change associated with chlorine was 0.22, while the change for turbidity and temperature was much smaller, 0.06 and 0.03 respectively. The change in R square indicates that the amount of variability in PC 4 accounted for by the regression curve increases as turbidity and temperature were added, but the magnitude of the change indicates that turbidity and temperature were of less importance than chlorine residual. The multiple R for all three independent variables was 0.56 (R square = 0.32).

The use of standardized regression coefficient (Beta) enables comparisons of regression coefficients and independent variables with different units (NTU, mg/liter and °C) to be made. The magnitude of the standardized regression coefficient reflects the relative importance of the associated variable. Chlorine residual was found to have the greatest effect on PC 4 (Beta = -0.38), followed by turbidity (Beta = 0.26) and temperature (Beta = 0.19). The equation of the regression curve is:

$$\log \text{PC } 4 = 0.67 - 0.93 \text{ (Cl residual, mg/liter)} + 0.34 \text{ (turbidity NTU)} + 0.02 \text{ (temperature, °C)}$$

All the regression coefficients were found to be significant at the 1% level ($B \neq 0$).

Similar data for PC 9 are shown in Table 14. Again, chlorine residual was found to have the greatest effect (Beta = -0.59), followed by turbidity

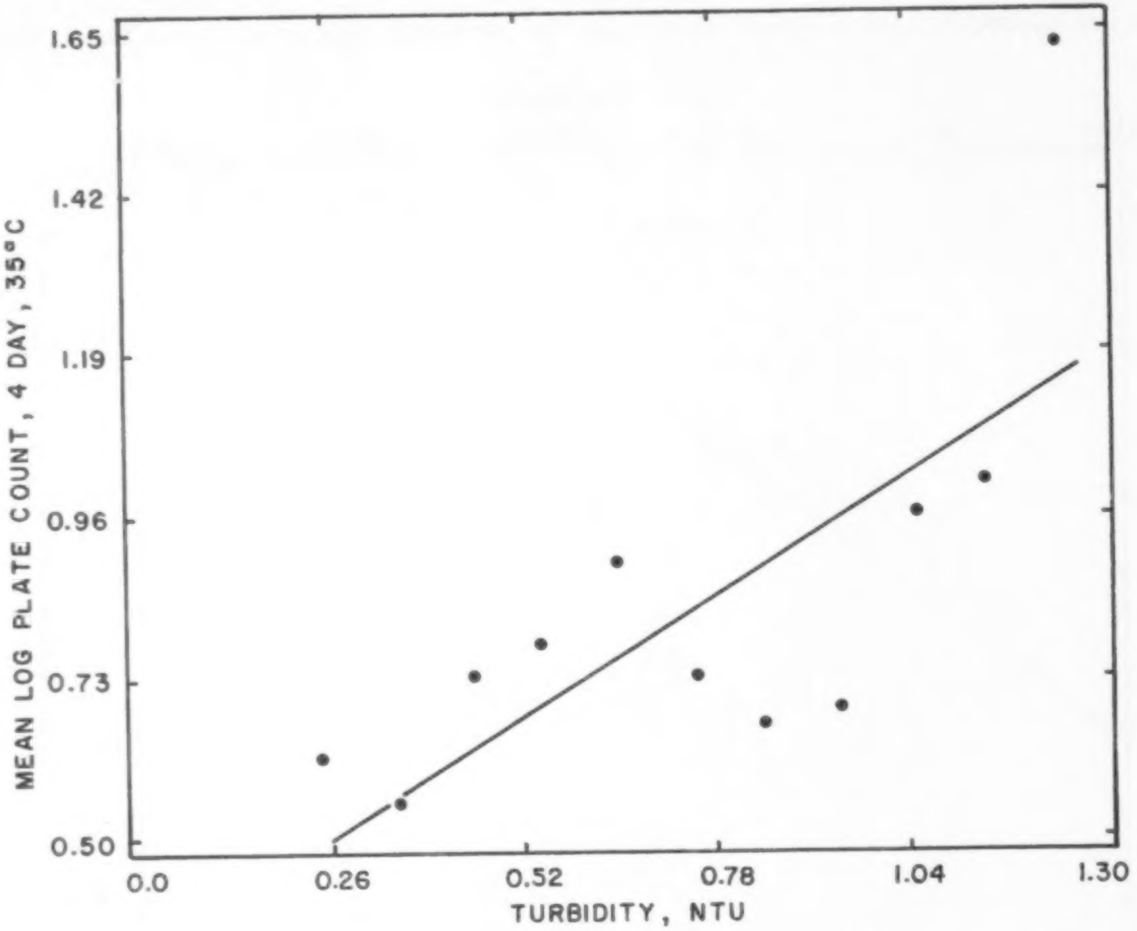

Figure 29. Relationship between the mean log 35°C plate count, 4 day incubation and turbidity, Baltimore.

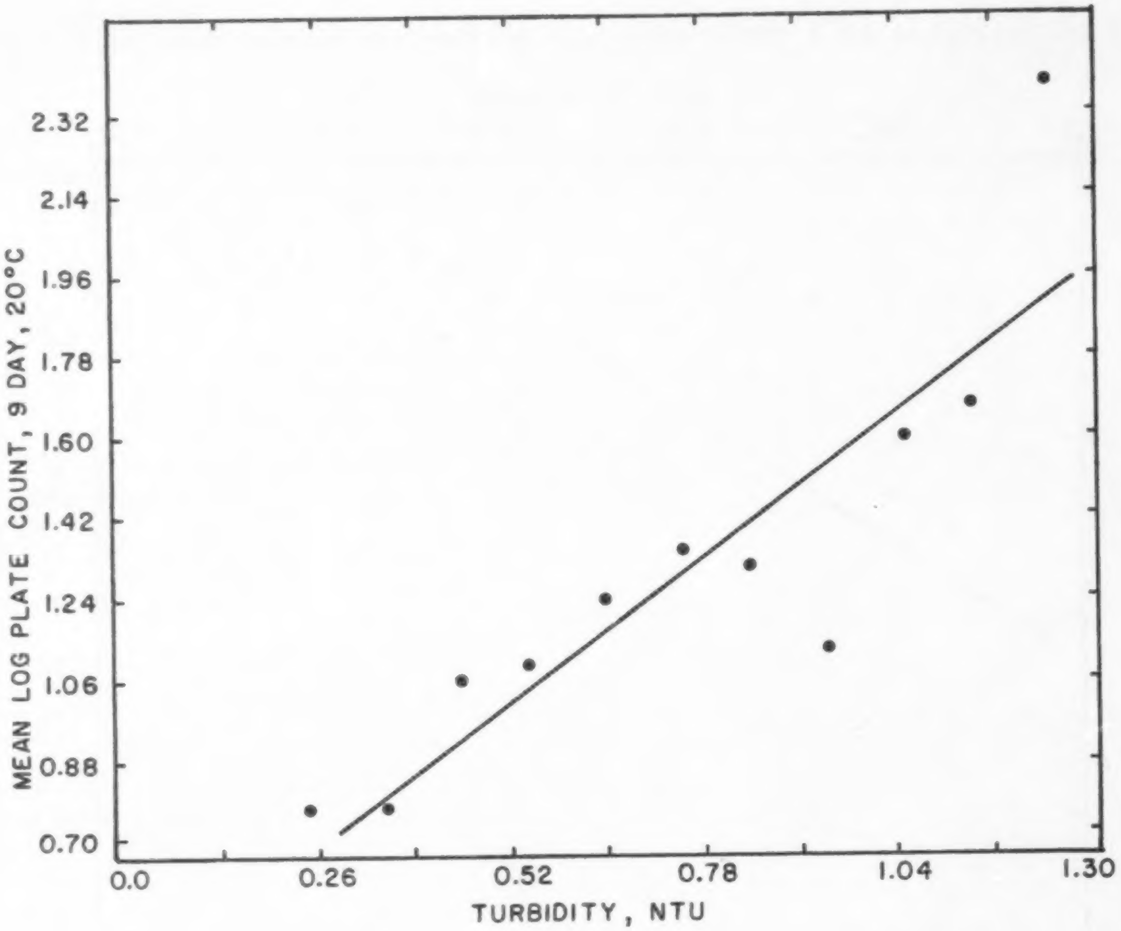

Figure 30. Relationship between the mean log 20°C plate count, 9 day incubation and turbidity, Baltimore.

TABLE 13. MULTIPLE LINEAR REGRESSION MODEL FOR THE 35°C, 4 DAY PLATE COUNT WITH FREE CHLORINE, TURBIDITY, AND TEMPERATURE VARIABLES ADDED SEQUENTIALLY

Dependent variable log PC 4

Variable	multiple R	R Square	R Square Change	Simple R	B[+]	Beta[++]	Std. Error B	F
free chlorine	.47	.22	.22	-.47	-.93	-.38	.08	154.2**
turbidity	.53	.28	.06	.34	.34	.26	.04	78.0**
temperature	.56	.32	.03	.27	.02	.19	.003	39.8**
constant					.67			

[+] B = regression coefficient

[++] Beta = standardized regression coefficient

** significant at 1% level

TABLE 14. MULTIPLE LINEAR REGRESSION MODEL FOR THE 20°C, 9 DAY INCUBATION PLATE COUNT WITH FREE CHLORINE, TURBIDITY AND TEMPERATURE VARIABLES ADDED SEQUENTIALLY

Dependent variable log PC 9

Variable	multiple R	R Square	R Square Change	Simple R	B[+]	Beta[++]	Std. Error B	F
free chlorine	.64	.41	.41	-.64	-2.02	-.59	.09	453.9**
turbidity	.66	.43	.03	.29	.31	.17	.05	41.3**
temperature	.66	.44	.003	.19	.009	.06	.004	4.3*
constant					1.75			

[+] B = regression coefficient

[++] Beta = standardized regression coefficient

** Significant at 1% level

* Significant at 5% level

(Beta = 0.17) and temperature (Beta = 0.06). The value for the multiple correlation coefficient 0.66 (R square = 0.44) was higher than that observed for PC 4. Generally, PC 9 was found to be more dependent on chlorine residual and less dependent on temperature. Temperature was not found to be significant at the 1% level for PC 9, but was significant at the 5% level. The equation of the regression curve for PC 9 is:

$$\log PC\ 9 = 1.75 - 2.02\ (\text{Cl residual, mg/liter}) + 0.31\ (\text{turbidity, NTU}) + 0.009\ (\text{temperature, °C})$$

A total of 123 samples were taken from 4 sampling stations in the Frederick water distribution system. The results were treated similarly to those from the Baltimore system, except that all calculations were done manually using a Texas Instrument TI-59 programmable hand calculator. Complete data for these samples are given in Appendix D. The correlation coefficient matrix for various parameters measured is given in Table 15. Significant positive correlation ($R \neq 0$ $p = 0.001$) was found between the two plate counts 35°C, 4 day incubation (PC 4), and 20°C 9 day incubation (PC 9), and turbidity. Significant negative correlation ($R \neq 0$ $p = 0.05$ to $p = 0.001$) was found between the two plate counts and free and total chlorine levels.

The greatest correlation, R = 0.92, was obtained between the 35°C, 4 day plate count and the 20°C, 9 day plate count. The equation for the regression line for these variables is:

$$PC\ 9 = 1.02(PC\ 4) + 0.07.$$

The slope of the line indicates that the bacterial counts obtained at 35°C were equal to those obtained at 20°C, as opposed to the Baltimore system where the 20°C counts were consistently higher.

The effect of turbidity on the mean log plate count values is shown in Figures 31 and 32. The mean log plate counts for ranges of turbidity in increments of 0.2 NTU were calculated and their values were plotted against midpoints of the turbidity ranges. As was observed for the Baltimore system, the mean plate count values showed higher correlation with turbidity than did the individual plate count values. The R value for the mean 35°C, 4 day plate count versus turbidity was found to be 0.89, and the equation for the line shown in Figure 31 is:

$$\log PC\ 4 = 0.61\ (\text{turbidity}) + 0.46$$

The R value for the mean 20°C, 9 day plate count is 0.87, and the equation for the line shown in Figure 32 is:

$$\log PC\ 9 = 0.59\ (\text{turbidity}) + 0.61$$

In Figures 33 and 34, mean log plate count values were plotted against midpoints of ranges of free and total chlorine levels. These ranges were 0.1 mg/ liter for free chlorine and 0.2 mg/liter for total chlorine. Again, higher correlations were obtained when mean values, rather than the

TABLE 15. CORRELATION COEFFICIENT MATRIX FOR CHEMICAL, PHYSICAL AND BIOLOGICAL DATA COLLECTED IN THE FREDERICK WATER DISTRIBUTION SYSTEM

	Turbidity	Free Cl	Total Cl	Log PC 4	Log PC 9
Turbidity	1.0	.04	-.07	.40***	.43***
Free Cl		1.0	.27**	-.24**	-.20*
Total Cl			1.0	-.41***	-.43***
Log PC 4				1.0	.92***
Log PC 9					1.0

* significant at 95% level

** significant at 99% level

*** significant at 99.9% level

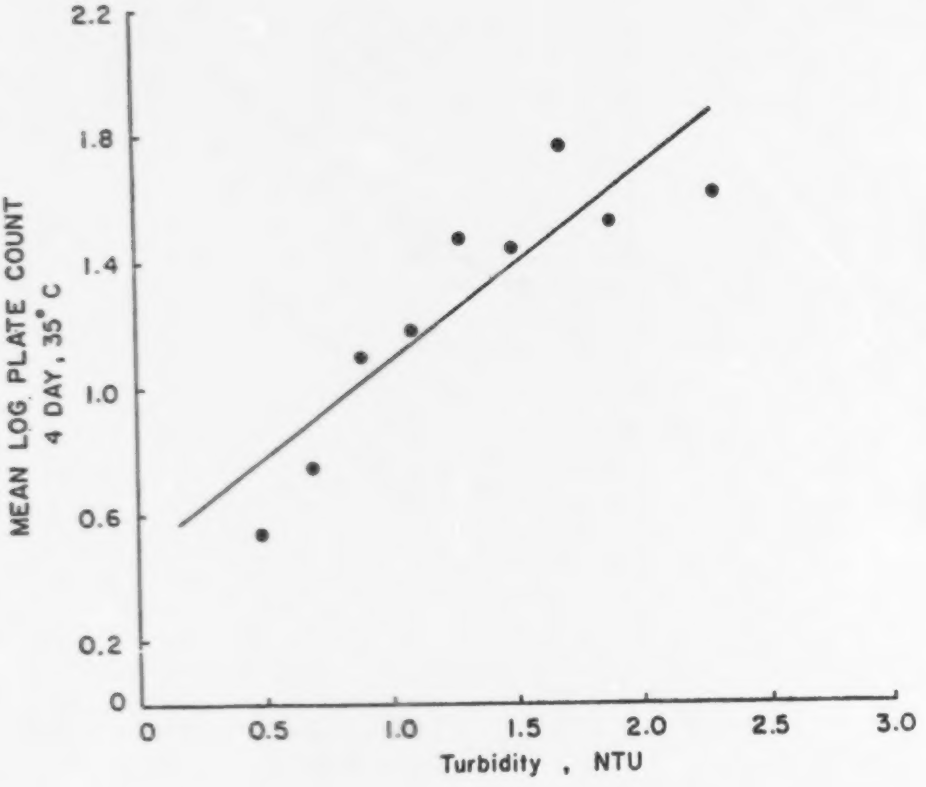

Figure 31. Relationship between the mean log 35°C plate count, 4 day incubation and turbidity, Frederick.

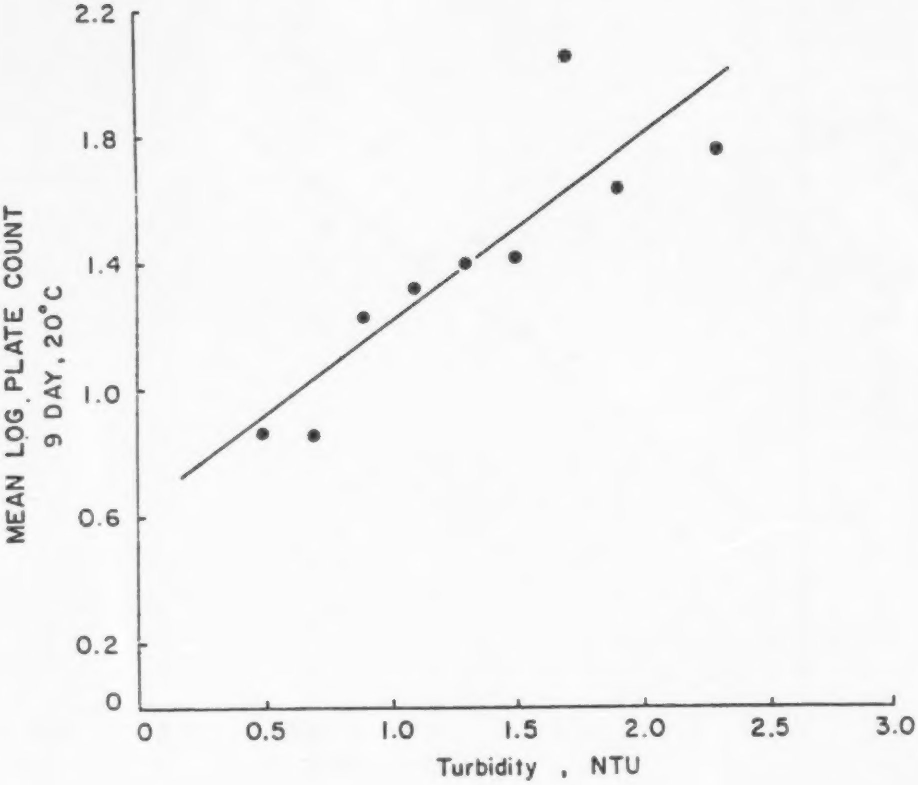

Figure 32. Relationship between the mean log 20°C plate count, 9 day incubation and turbidity, Frederick.

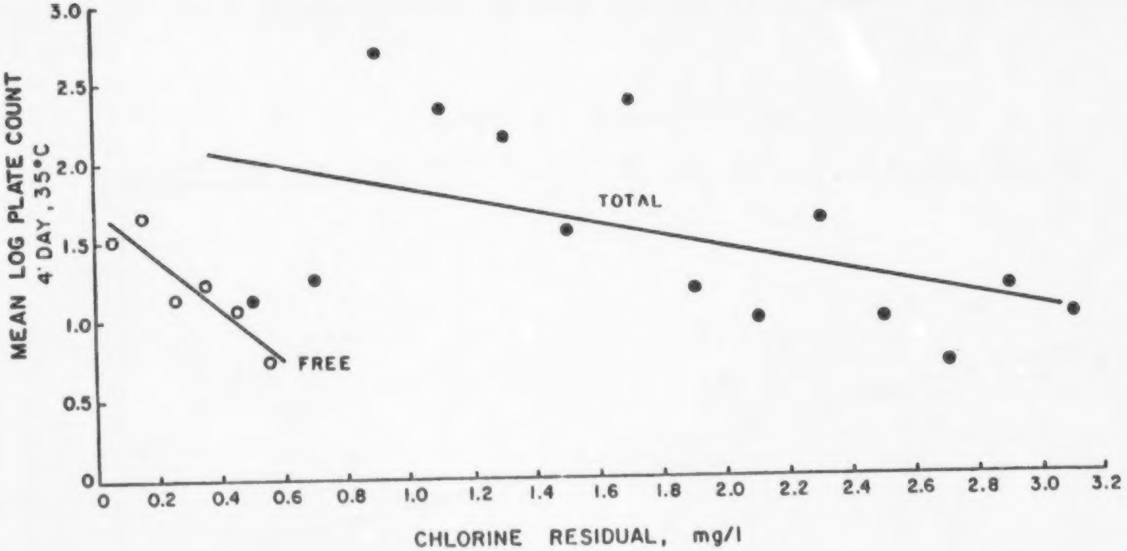

Figure 33. Relationship between the mean log 35°C plate count, 4 day incubation, and the free fraction and the total chlorine residual, Frederick.

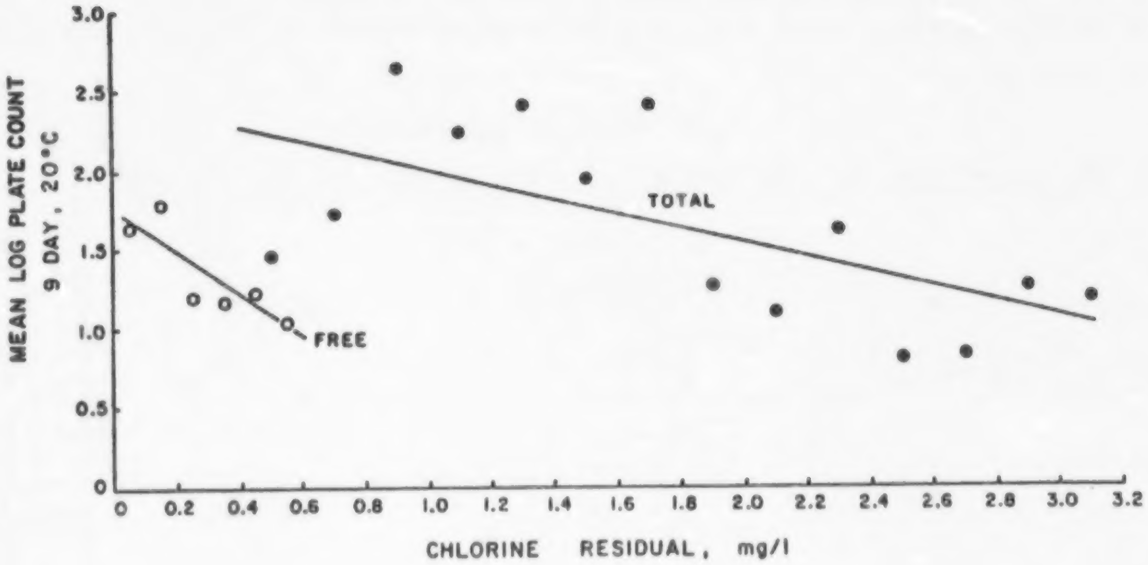

Figure 34. Relationship between the mean log 20°C plate count, 9 day incubation, and free fraction and the total chlorine residual, Frederick.

individual values were considered. It is important to note that the Frederick system employs the chlorine-ammonia process with a resulting high total chlorine and low free chlorine residual. Thus, the curves shown for free chlorine residuals are not for free chlorine alone, but for the free fraction of a relatively high total chlorine residual. The free and total residuals were found to be correlated with each other with an R value of 0.27. The equation for the free chlorine line for PC 4 in Figure 33 is:

$$\text{mean log PC 4} = -1.61 \text{ (free Cl)} + 1.72$$

while the equation for the total chlorine line is:

$$\text{mean log PC 4} = -0.39 \text{ (total Cl)} + 2.23$$

with R values of -0.90 and -0.52, respectively. For the 20°C, 9 day plate count shown in Figure 34, the equation for the free chlorine line is:

$$\text{mean log PC 9} = -1.33 \text{ (free Cl)} + 1.76$$

for the total chlorine line:

$$\text{mean log PC 9} = 0.47 \text{ (total Cl)} + 2.50$$

with R values of -0.85 and -0.65, respectively. In both instances, the mean log plate count shows a greater dependence, as evidenced by the larger negative slope on the free chlorine fraction of the total chlorine residual than the total residual. The large difference in mean plate count values between the 0 - 0.1 mg/liter range and 0.11 - 0.2 mg/liter range for free chlorine, which appeared in the Baltimore system, was not found for the Frederick samples. The lack of agreement in these results between the two systems may be due to two factors. Many of the samples from Baltimore that fell within the range 0 - 0.1 mg/liter had no chlorine residual, while most of the Frederick samples in this range had some apparent measurable free chlorine residual. Also, the Frederick samples had a relatively high total chlorine residual, which was absent in the Baltimore samples.

Microbial Differentiation--

A total of 6506 colonies were picked from the standard plate count agar incubated at 20°C and 35°C and tested for catalase activity, oxidase, motility, indole production, anaerobic growth and acid production from glucose (aerobic and anaerobic). The isolates were assigned to arbitrary numbered groups on the basis of the pattern obtained with these seven tests. A total of 43 different groups were found within the 6506 isolates. Gram reaction, nitrate reduction, citrate utilization, and growth on MacConkey agar were determined for a portion of the isolates in each group to obtain further information and to evaluate homogeneity within the group. The 20 major groups, comprising 90% of the total isolates tested, are shown in Table 16. The groups are ranked in decreasing order of predominance at 35°C. A further description of the groups follows.

TABLE 16. MAJOR BIOCHEMICAL GROUPS ISOLATED FROM PLATE COUNTS FROM THE BALTIMORE AND FREDERICK, MARYLAND WATER DISTRIBUTION SYSTEMS

Group	Facultative Anaerobe	Acid from Glucose Anaerobically	Acid from Glucose Aerobically	Catalase Activity	Oxidase	Motility	Indole	20°C number Isolated (% of Total	35° number Isolated (% of Total)
8	-	-	-	+	+	-	-	740 (21.3)	598 (19.7)
9	-	-	-	+	-	-	-	963 (27.8)	415 (13.7)
26	+	-	-	-	-	-	-	185 (5.3)	212 (7.0)
3	-	-	-	+	+	+	-	217 (6.3)	192 (6.3)
24	+	-	-	+	-	+	-	181 (5.2)	184 (6.1)
17	+	-	-	+	-	-	-	170 (4.3)	162 (5.3)
10	+	+	+	+	+	+	+	38 (1.1)	155 (5.1)
18	-	-	-	+	-	+	-	120 (3.5)	98 (3.2)
22	+	-	-	+	+	+	-	167 (4.8)	97 (3.2)
5	-	-	+	+	+	-	-	60 (1.7)	83 (3.1)
13	+	+	+	+	-	+	-	19 (.5)	67 (2.2)
16	+	+	+	+	-	-	-	13 (.4)	65 (2.1)
28	+	+	+	+	+	-	+	33 (1.0)	64 (2.1)
6	-	-	+	+	-	-	-	45 (1.3)	63 (2.1)
14	+	-	+	+	+	-	-	44 (1.3)	52 (1.7)
11	+	+	+	+	+	+	-	58 (1.7)	48 (1.6)
27	+	+	+	+	+	-	-	35 (1.0)	46 (1.5)
1	-	-	+	+	+	+	-	31 (.9)	37 (1.2)
30	+	-	+	+	-	-	-	5 (.1)	32 (1.1)
2	-	-	+	+	-	+	-	34 (1.0)	25 (.8)
							TOTAL	3158 (91.1)	2695 (89.1)

Gram negative aerobic nonsaccharolytic rods--

Group 8 -- Gram stains were performed on 152 isolates in group 8, of which 144 (95%) were Gram negative rods, 5 (3%) were Gram positive rods and 3 (2%) were Gram positive cocci. Yellow pigmentation was common within group 8, with 38% of the isolates at 20°C and 50% of the isolates at 35°C having this characteristic. The results for the additional tests for group 8 were as follows:

nitrate reduction	growth on MacConkey	citrate utilization	number obtained/number tested	%
-	-	-	59/87	(68)
+	-	-	16/87	(18)
-	+	+	6/87	(7)
+	+	+	6/87	(7)

Group 8 appears to be fairly homogeneous, with 68% of the members of this group showing one pattern on the three tests.

Group 9 -- Group 9 is composed predominantly of Gram negative rods, with 190 (93%) of the isolates examined falling into this category while 8 (4%) were Gram positive cocci and 6 (3%) were Gram positive rods. On the basis of the three additional tests, this group was also fairly homogeneous, as shown below:

nitrate reduction	growth on MacConkey	citrate utilization	number obtained/number tested	%
-	-	-	121/156	(78)
+	+	+	13/156	(8)
+	+	-	11/156	(7)
+	-	-	7/156	(4)
-	+	+	3/156	(2)
-	-	+	1/156	(1)

83% of the isolates at 20°C were yellow, while 51% at 35°C were yellow.

Group 3 -- Of the 83 isolates in group 3 examined for Gram stain, 76 (92%) were Gram negative rods and 7 (8%) were Gram positive rods. Yellow pigmentation was less prevalent in this group, with 20% of the isolates at 20°C and 11% at 35°C showing this pigmentation. Three patterns were obtained with the three additional tests, as shown below. The triple negative pattern was again the most prevalent, with 67% of the isolates examined in group 3 showing this pattern:

nitrate reduction	growth on MacConkey	citrate utilization	number obtained/number tested	%
-	-	-	46/69	(67)
+	-	-	15/69	(22)
+	+	-	8/69	(11)

Group 18 -- Since this group composed a smaller fraction of the total number of isolates, fewer members of this group were examined. 28 isolates were Gram stained, of which 24 (86%) were Gram negative rods, 3 (11%) were Gram positive rods and 1 (3%) was a Gram positive coccus. Considerable heterogeneity was found for nitrate reduction, growth on MacConkey agar and utilization of citrate. 63% of the isolates at 20°C, and 86% of the isolates at 35°C demonstrated yellow pigmentation.

nitrate reduction	growth on MacConkey	citrate utilization	number obtained/number tested	%
-	-	-	7/12	(58)
-	+	+	4/12	(33)
+	+	+	1/12	(9)

Although positive identification of bacteria in these groups cannot be made on the basis of the limited number of tests utilized, a tentative identification is possible. Possibilities for groups 8, 9, 3 and 18 include the *Pseudomonadaceae, Flavobacterium, Alcaligenes,* and *Moraxella*.

Gram negative facultative nonsaccharolytic rods--

Group 26 -- Group 26 is composed of 95% (38/40) Gram negative rods and 5% (2/40) Gram positive rods. Approximately half of the isolates in this group were pigmented yellow, 55% at 20°C and 51% at 35°C. Results of nitrate reduction, growth on MacConkey and citrate utilization were as follows:

nitrate reduction	growth on MacConkey	citrate utilization	number obtained/number tested	%
-	-	-	23/27	(85)
+	-	-	4/27	(15)

Group 24 -- This group was composed almost entirely of yellow pigmented Gram negative rods. Of the 65 isolates examined for Gram stain 64 (98%) were Gram negative rods and 1 (2%) was a Gram positive rod. 78% of the isolates at 20°C and 84% at 35°C showed yellow pigmentation. This group was homogeneous with respect to nitrate reduction, growth on MacConkey and citrate utilization with the triple negative pattern predominant.

nitrate reduction	growth on MacConkey	citrate utilization	number obtained/number tested	%
-	-	-	47/57	(82)
+	+	+	4/57	(7)
+	-	-	3/57	(5)
-	+	-	1/57	(2)
+	+	-	2/57	(4)

Group 17 -- Group 17 is similar to group 24 in that many of the isolates showed yellow pigmentation, 81% at 20°C and 63% at 35°C. 91% of the isolates (86/95) were Gram negative rods, 5% (5/95) were Gram positive cocci and 4% (4/95) were Gram positive rods. The results for nitrate reduction, growth on MacConkey, and citrate utilization indicate that this group is homogeneous with respect to these tests.

nitrate reduction	growth on MacConkey	citrate utilization	number obtained/number tested	%
-	-	-	72/81	(89)
-	-	+	5/81	(6)
+	-	-	3/81	(4)
+	+	+	1/81	(1)

Group 22 -- Group 22 contained 98% (50/51) Gram negative rods and 2% (1/51) Gram positive rods. This group differed from the other 3 in this category in that it contained a low percentage of yellow pigmented colonies, 45% at 20°C and 26% at 35°C and showed more diversity in the three additional tests run.

nitrate reduction	growth on MacConkey	citrate utilization	number obtained/number tested	%
-	-	-	16/26	(61)
+	-	-	9/26	(35)
-	+	-	1/26	(4)

Majority of bacteria in groups 26, 24, 17 and 22 were consistent with the biochemical characteristics of the *Flavobacterium*.

Gram positive or negative aerobic saccharolytic rods--

Groups 5, 6, 1 and 2 -- The aerobic-saccharolytic category contained both Gram positive and Gram negative rods and a low percentage of pigmented colonies as shown below:

group	Gram reaction		% yellow colonies	
	positive rod	negative rod	20°C	35°C
5	6	8	22	10
6	7	5	27	11
1	21	7	0	0
2	-	-	9	2

In addition, 2 Gram positive cocci were obtained, 1 in group 5 and 1 in group 6. Since these 4 groups accounted for only 5.8% of the total number of isolates they were not tested for nitrate reduction, growth on MacConkey and citrate utilization. Gram positive organisms within this category show charactertistics consistent with the bacillus group, while the Gram negative organisms can be tentatively identified as *Pseudomonadaceae*.

Gram negative facultative saccharolytic rods--

Groups 10, 11 and 27 -- Isolates in these groups are characterized by positive reactions on most of the biochemical test runs. A total of 46 isolates were examined for Gram reaction and morphology; 31 in group 10, 12 in group 11, and 3 in group 27. All were Gram negative rods. Yellow pigmentation was generally absent, 0% at 20°C and 4% at 35°C for group 10, 9% at 20°C and 0% at 35°C for group 27, and 0% for group 11 at both temperatures. Nitrate reduction, growth on MacConkey and citrate utilization were done on 11 isolates in group 10. All 11 isolates were positive on these three tests. These organisms can be tentatively identified as *Aeromonas*.

Facultative saccharolytic microorganisms--

Groups 13, 16, 28 -- These groups differ from the preceding groups 10, 11 and 27 in that they contain a higher percentage of Gram positive organisms.

group	Gram negative rod	Gram positive rod	Gram positive coccus
13	2	2	1
16	10	3	13
28	11	0	6

Yellow pigmentation within groups 13, 16 and 28 varied from 0 to 15%. Possible identification for the Gram positive coccus is *staphylococcus*, while the Gram positive rods may be tentatively identified as bacillus and the Gram negative as *Enterobacteriaceae*.

Distribution of Microorganisms by Sampling Sites--The 20 major groups shown in Table 16 are ranked in the order of predominance at 35°C. The trend obtained at 20°C was generally the same as is also shown in Table 16. Groups 8 and 9 were isolated in the greatest number, with 49.1% of the total isolates at 20°C and 33.4% of the total isolates at 35°C belonging to these two groups.

Data shown in Table 16 are broken down by station in Appendix E. This appendix gives the number of isolates in each group and the frequency of isolation of each group at each station. This information was used to generate an index of the relative importance of each group at each station, using the following equation:

$$I = F \times N \times \left(\frac{100}{F_{max} \times N_{max}} \right)$$

where:

1 is the index

F is the frequency of isolation of the group as a fraction of 1.0

N is the number of isolates in the group

N_{max} is the number of isolates in the most prevalent group of any given station

F_{max} is the frequency for N_{max}

It can be seen then when $N = N_{max}$ and $F = F_{max}$, then $I = 100$. The index, then, is simply the product of the number of isolates and the frequency, normalized to 100. The index is given for each of the groups at each station in Figures 35 through 42. Stations 1 and 4 are in the Frederick distribution system, while the remaining stations are in Baltimore. Station 1 contributed many of the facultative, saccharolytic organisms (groups 10, 11, 27, 13, 16 and 28) encountered in this survey. Figure 35 shows that while group 3 was predominant at 35°C at station 1, group 10 had an index close to 100 and groups 13 and 16 also had fairly high indices. Of the total number of isolates in groups 10, 13, and 16 at 35°C, 40%, 72% and 66%, respectively, came from station 1. Although the indices for groups 11, 27 and 1 were low because of a low number of isolates, the contribution of station 1 was high for these groups at 35°C with 44%, 76% and 46% of the total isolates respectively. Group 10 was found only at 3 stations, number 1, 27 and 44, and was obtained primarily at 35°C. The occurrence of group 27 paralleled that of group 10, although at much lower levels. For the 20°C isolates at station 1, groups 3 and 8 were predominant. Figure 36 gives the indices for station 4, the other Frederick station. Groups 8 and 9 were predominant at both temperatures. The remaining Figures 39 through 42 show the frequency-level index for the Baltimore stations. Generally, 2 to 4 groups predominate at each station at both temperatures. Although predominant

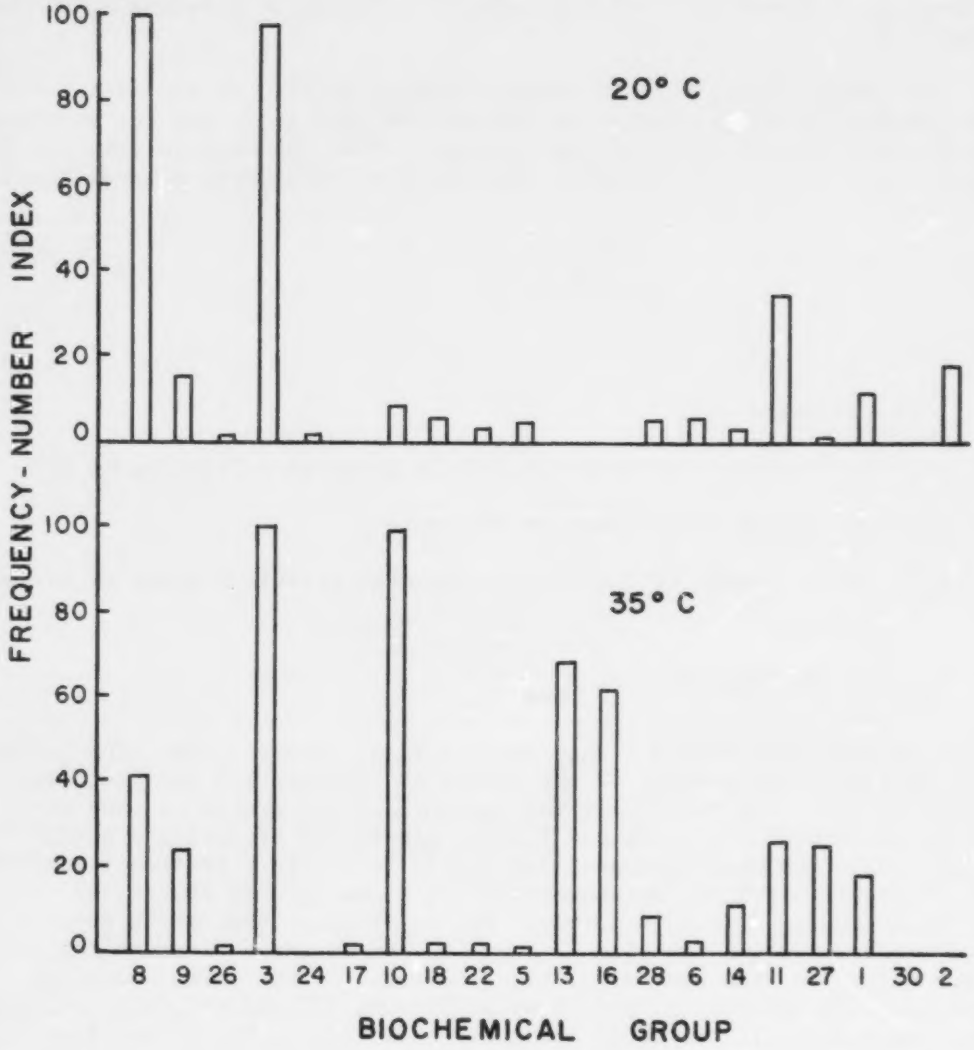

Figure 35. Relative occurrence of the different biochemical groups, as shown by the frequency-number index, at station 1 in the Frederick distribution system.

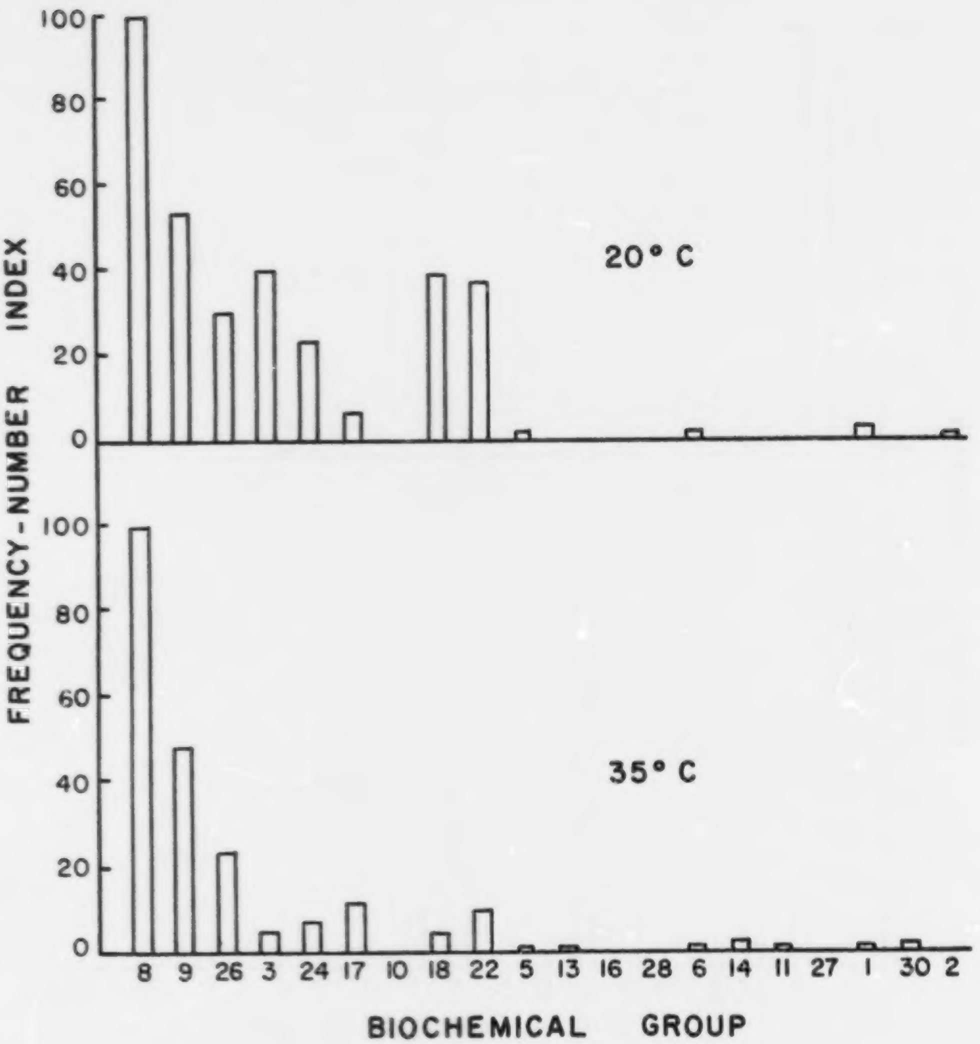

Figure 36. Relative occurrence of the different biochemical groups, as shown by the frequency-number index, at station 4 in the Frederick distribution system.

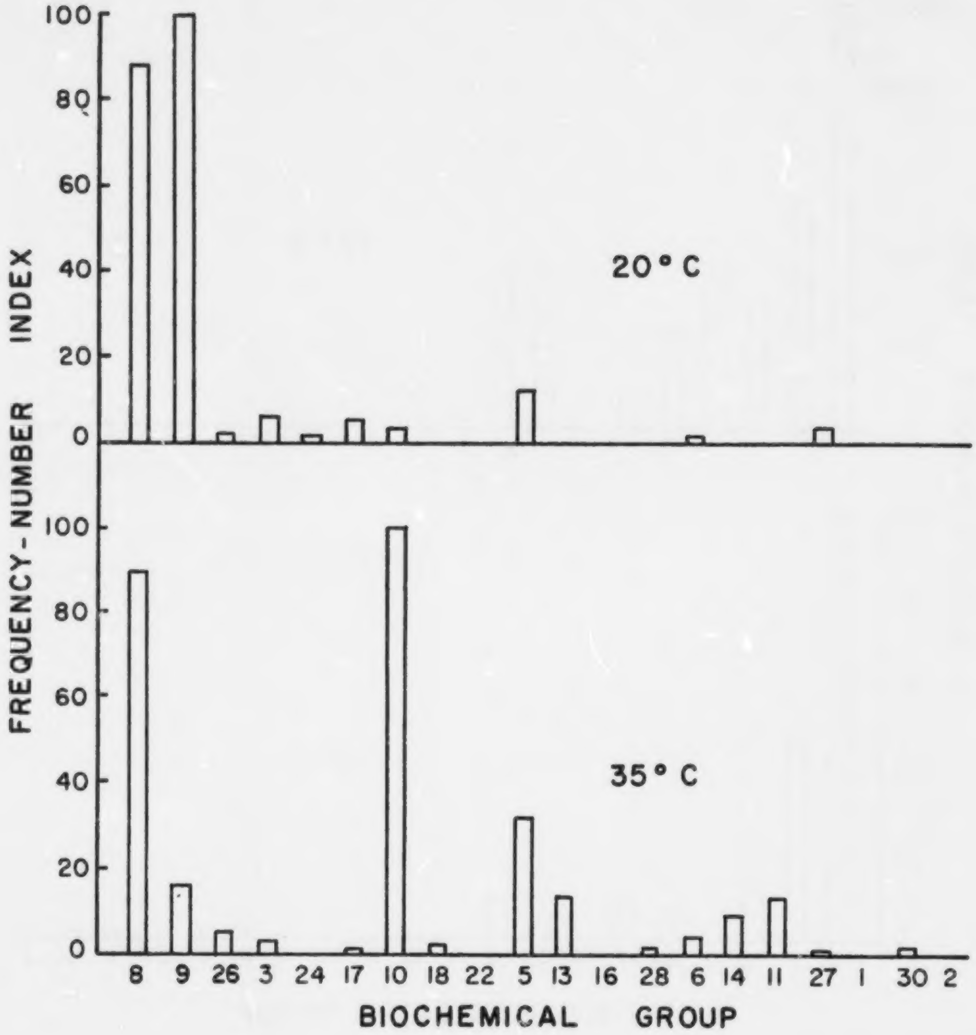

Figure 37. Relative occurrence of the different biochemical groups, as shown by the frequency-number index, at station 27 in the Baltimore distribution system.

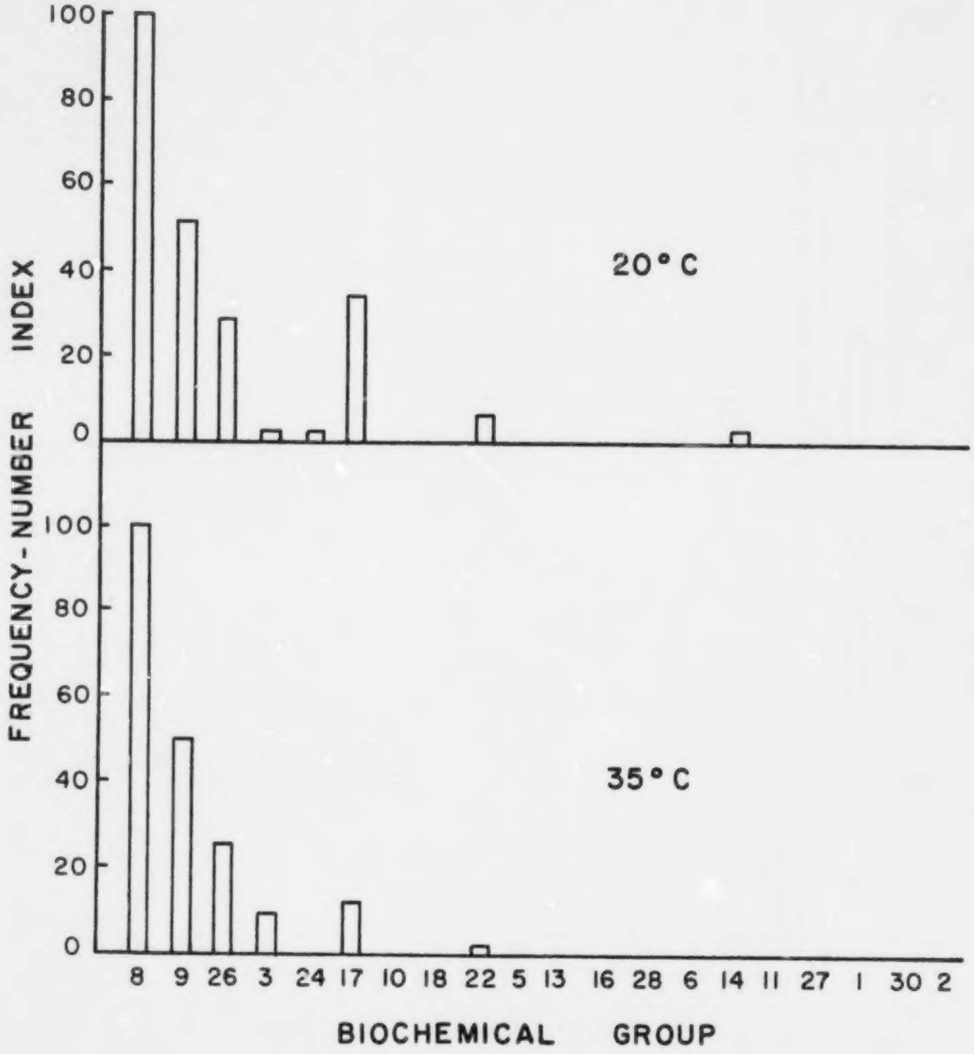

Figure 38. Relative occurrence of the different biochemical groups, as shown by the frequency-number index, at station 34 in the Baltimore distribution system.

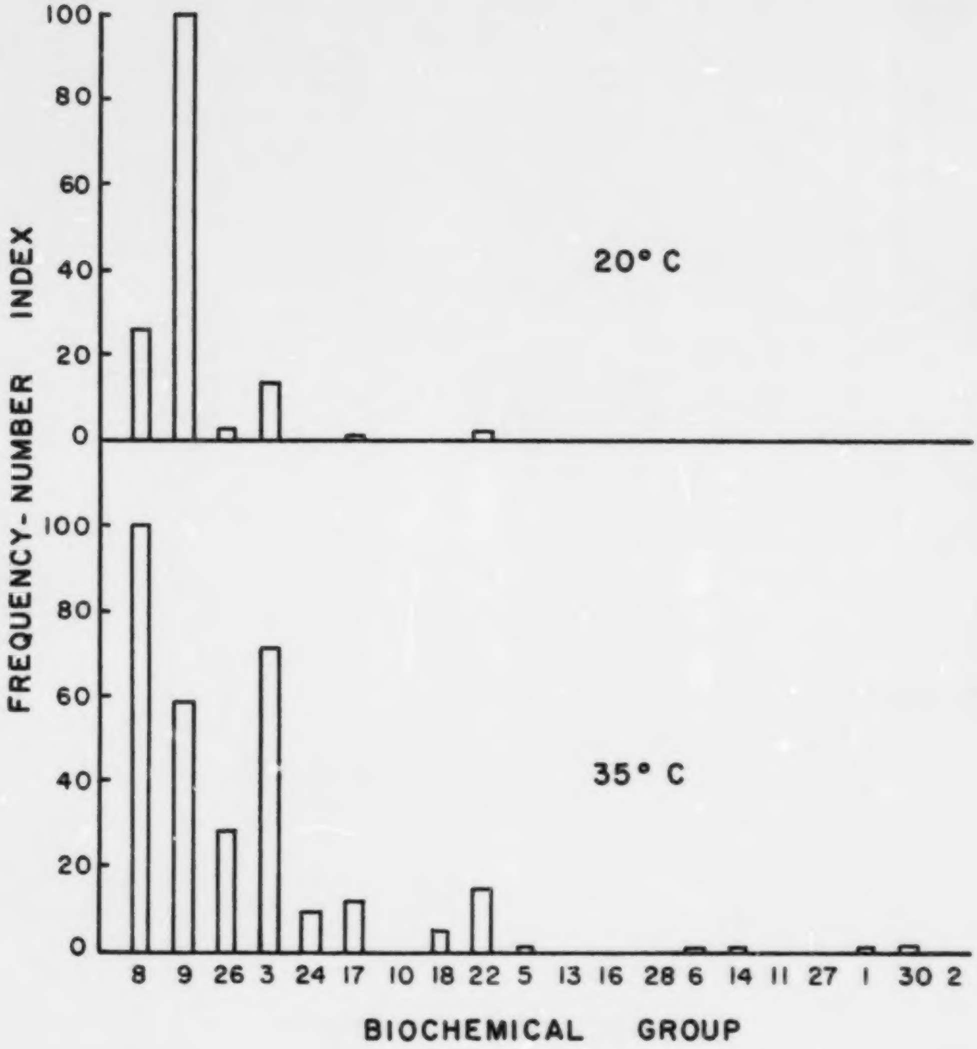

Figure 39. Relative occurrence of the different biochemical groups, as shown in the frequency-number index, at station 37 in the Baltimore distribution system.

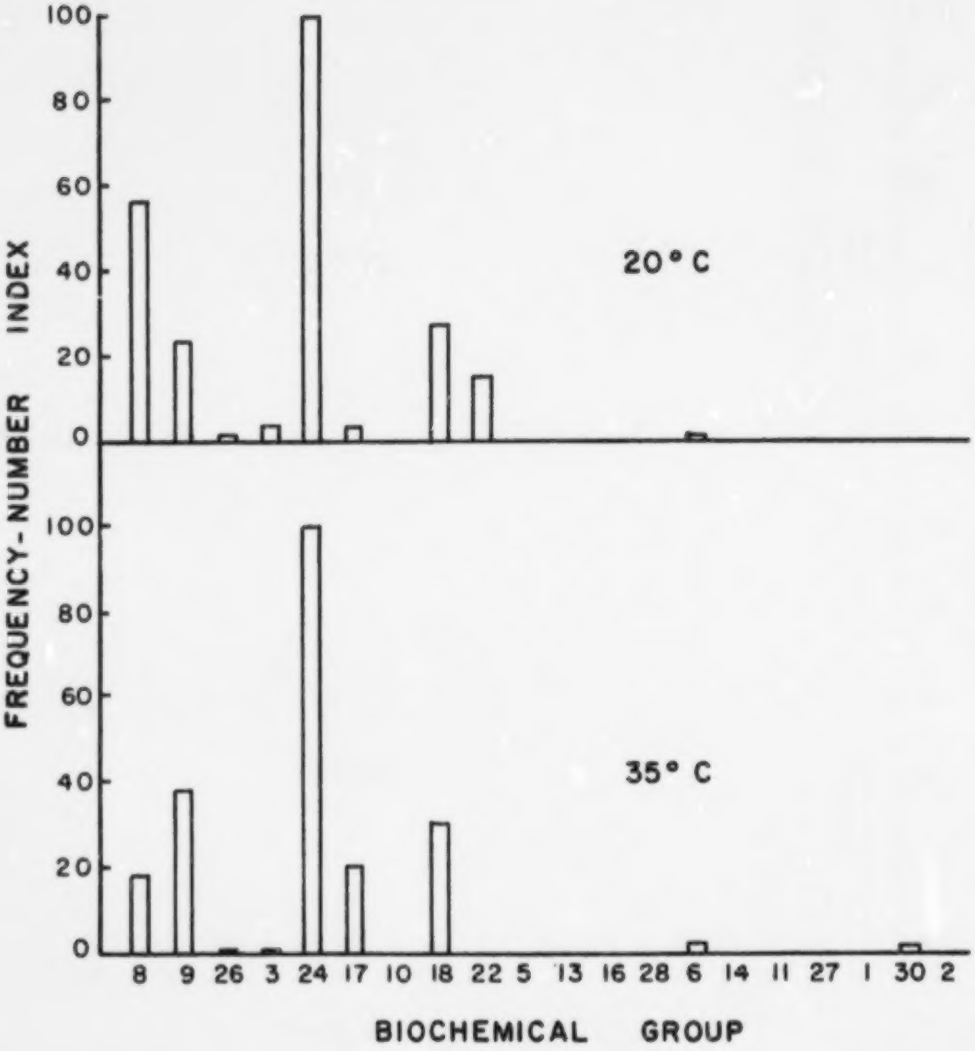

Figure 40. Relative occurrence of the different biochemical groups, as shown by the frequency-number index, at station 43 in the Baltimore distribution system.

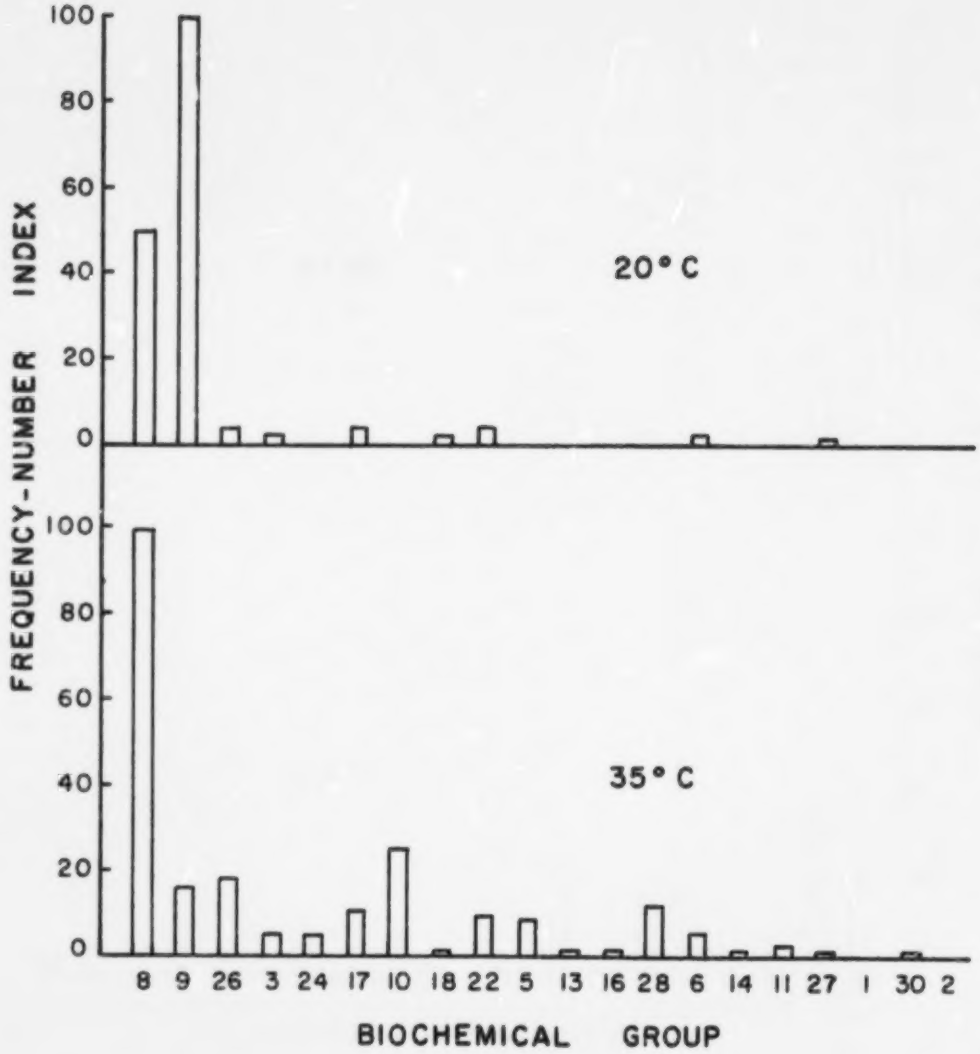

Figure 41. Relative occurrence of the different biochemical groups, as shown by the frequency-number index, at station 44 in the Baltimore distribution system.

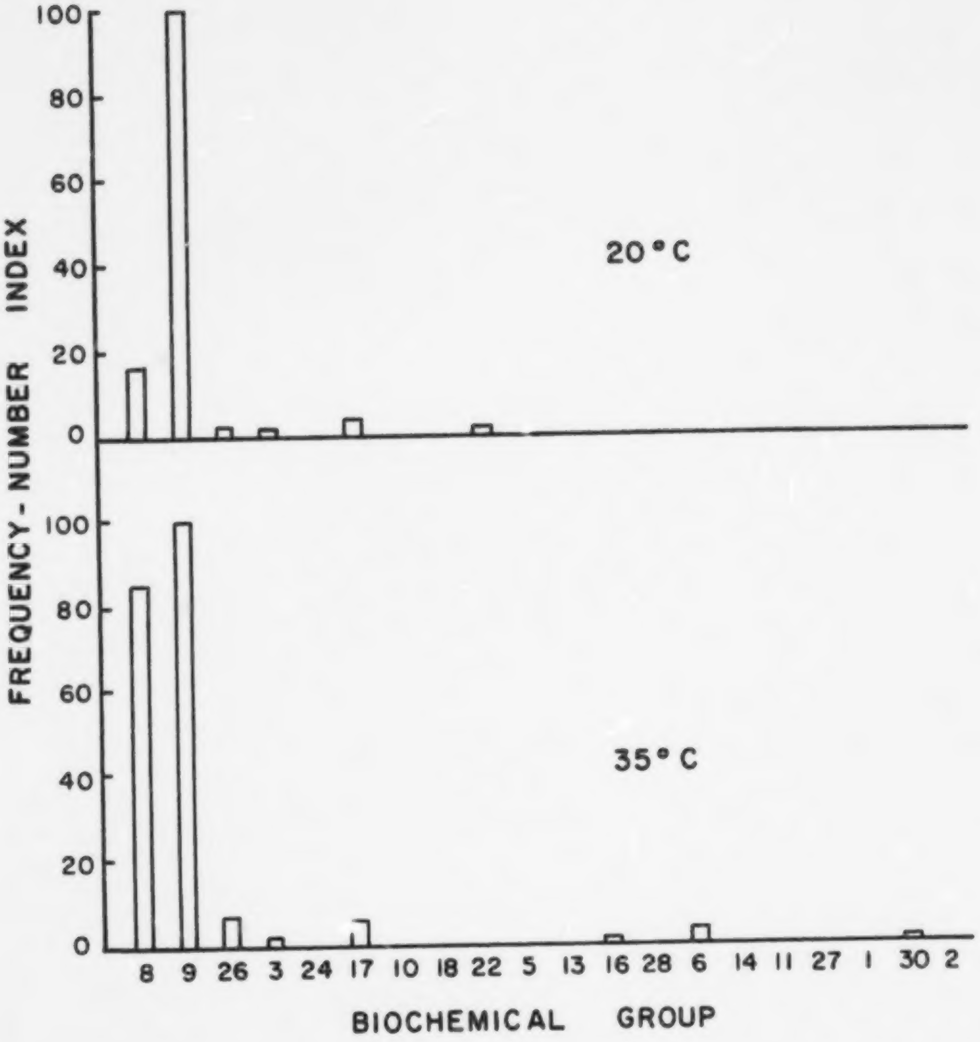

Figure 42. Relative occurrence of the different biochemical groups, as shown by the frequency-number index, at station 48 in the Baltimore distribution system.

groups vary in biochemical characteristics from station to station, they were generally the nonsaccharolytic organisms.

SECTION 7

DISCUSSION

HOLDING TANK AND RESERVOIR STUDIES

Simulated Contaminant

Unfiltered raw sewage was used as the contaminant base for the holding tank and reservoir studies to provide a source of chlorine demand since raw sewage has often been implicated in post treatment contamination of water distribution systems. For the holding tank studies, the raw sewage was autoclaved and stored for use to provide reproducible data and thereby to minimize confounding effects of variations in the chemical, physical and biological qualities of fresh samples of raw sewage. After minor changes upon sterilization, the chemical, physical and biological parameters (including chlorine dosage required for breakpoint) were stable for up to 30 days. While the autoclaved raw sewage seeded with the test microorganisms was artificial, the data obtained in the laboratory holding tank studies did provide a firm data base for subsequent comparison. Reservoir studies utilized raw unfiltered sewage from Fort Meade sewage treatment plant number 2. This sewage was not autoclaved and was seeded with f2 bacterial virus. While data from the reservoir studies were more variable, it was noted that naturally occuring coliforms were more resistant to chlorine than the freshly isolated member of the coliform group used in the holding tank studies.

Mixing and Flow Regimen

Holding tank studies were of completely mixed systems without additional inflows and represented one of the worst contamination conditions that might be encountered in a water supply system. The holding tank studies were designed to provide an estimate of the strength and volume of contaminant that can be neutralized by the chlorine residuals under the experimental conditions, the relative survival of test microorganisms, and the relative efficiencies of the types of chlorine residuals. The reservoir studies provided information of the effect of added flow. Since the reservoir system was found to be completely mixed during the "draw and fill" operation, the information obtained would be more indicative of small storage tanks and reservoirs rather than larger units where complete mixing may not occur. In the draw and fill operation not only did agitation occur, but fresh disinfectant was also introduced to neutralize the contaminant.

Microbial Inactivation

The inactivation of microorganisms in water with chlorine is influenced by pH, temperature, disinfectant concentration, and by chlorine consuming interfering substances. The efficiency of chlorine residuals in the water distribution system, when challenged with a contaminant, was similarly dependent upon these same factors. The water in most municipal distribution systems is slightly alkaline due to the addition of lime at the clear well for corrosion control. Experiments were, therefore, conducted at pH 8 to reflect the pH of the water in the distribution system. At pH 8, the predominant species of free chlorine is hypochlorite ion and the predominant species of combined chlorine is monochloramine.

Microorganisms in sewage introduced as contaminant in water can be neutralized by the residual chlorine. An estimate of the amount of sewage that can be added to tap water containing free chlorine residual with assurance of rapid microbial inactivation can be calculated from the chlorination breakpoint of the contaminant. For sewage with a breakpoint of 100 mg/liter, 1% by volume is required to consume 1 mg/liter free chlorine in tap water. Since free chlorine has been shown to be an effective bactericide and viricide, rapid inactivation can be expected when a free chlorine residual is present. The autoclaved raw sewage used in these experiments had a chlorination breakpoint above 100 mg/liter (150-270 mg/liter). Free chlorine was, therefore, generally not detected 120 minutes after the addition of 1% sewage to tap water with an initial 1 mg/liter free chlorine residual. Only when the challenge reached 5% did the 1 mg/liter free chlorine residual fail to provide at least 90% inactivation of bacteria and poliovirus. Longer contact times were required for equivalent bacterial inactivation when the initial chlorine residual was the combined form, while equivalent viral inactivation was rarely achieved with the combined residual. In reservoir studies, where the chlorine was replenished, greater inactivation was observed at higher sewage contamination levels.

The species of chlorine present in the distribution system decidedly affects the residual performance. A free chlorine residual affords more protection than an equivalent level of combined chlorine under the same environmental conditions. Free chlorine was a more potent and faster acting bactericide and viricide for each of the conditions of pH, temperature and sewage challenge. In addition, a free chlorine residual can serve as a "marker" for contamination, since free chlorine will react rapidly with contaminant material. In a system where free residual chlorine is normally maintained, the absence of a free residual is evidence that chlorine demanding substances may have entered the system. Chemical results obtained in these experiments indicate that a total chlorine residual is present even after the addition of sizeable amounts of contaminant so that the detection of a combined chlorine residual does not assure water potability. The relative inefficiency of a combined chlorine residual in protecting against contaminatory materials, and its failure to act as a "marker" indicates that the addition of ammonia to create chloramines purposely is contrary to good public health practice.

It is important to emphasize that the use of free chlorine as a marker or flag is heavily dependent upon the ability to measure free chlorine in the field and on the chlorine residual history in the distribution system. Despite the existence of numerous color tests and field procedures for the determination of chlorine, a reliable, sensitive and specific test for free available chlorine is not yet available. Cooper *et al.* (1974) compared chlorine determinations by the modified orthotolidine-arsenite, stabilized neutral orthotolodine (SNORT), leuco crystal violet, N, N-diethyl-p-phenylene diamine (DPD) and syringaldazine (FACTS) tests. In the hands of operators, all except syringaldazine, yielded false positive readings for free chlorine. The FACTS procedure was however, the least sensitive of the methods tested. DPD has since been modified to the DPD steadiFAC by the addition of thioacetamide to enhance free chlorine specificity, (Palin, 1978) and FACTS has been modified to increase sensitivity (Cooper *et al.*, 1975). The presence or absence of free chlorine is difficult to interpret unless the chlorine residual history at a given sample station is known. Several stations in the Baltimore City distribution system consistently have zero free chlorine in late summer months. The absence of free chlorine at these stations at this time of year does not suggest any post treatment contamination. The conspicuous absence of free chlorine at a station where free chlorine was continually observed should, however, deserve serious attention.

The free chlorine residual is more difficult to maintain than a combined chlorine residual. Converting a distribution system to free chlorine requires considerable effort and patience. Several months or years at elevated chlorine levels are often required to "push" a free chlorine residual into the distribution system. (Umbenhauer, 1959; Buelow and Walton, 1971). A free chlorine residual is sometimes impossible to maintain in systems where excessive corrosion, tuberculation and scaling are found.

The free chlorine residual may contribute to the formation of chlorinated organics in low concentrations. The formation of chloroform and other trihalomethanes (THM's) are dependent on the presence of free chlorine. The role of the distribution system on the THM formation, however, remains to be evaluated.

In this study several test organisms were simultaneously exposed to inactivating conditions, so that comparisons of the susceptibilities could be made. The coliform organism, *S. typhimurium,* and *S. sonnei* were inactivated at the same rate, but poliovirus 1 was more resistant and f2 the most resistant. Reductions of poliovirus to the sensitivity limit of the assay did occur under some conditions, but similar inactivation of the f2 bacterial virus was rare. Thus, while bacterial inactivation may be achieved under many conditions, infectious viral particles could be carried to the consumer. An organism similar in resistance to f2 would only be inactivated where the level of introduced contaminant was small and free chlorine was present. Combined chlorine residuals were relatively poor viricides.

Little growth was observed in any of the test microorganisms in test conditions. The extended time studies suggest that the trend on prolonged storage was further die-away. However, samples that contained high levels of sewage, where little if any inactivation occurred, occasionally yielded increases in bacterial numbers as did some of the dechlorinated controls.

Ideally, the disinfectant residual should protect against infectious microorganisms up to the point where the contamination becomes visible to the consumer. This criterion was met, for bacterial contamination, by an initial 1 mg/liter free chlorine residual. Protection was conferred up to the addition of 1% sewage, at which point the water has a noticeable turbidity. An initial 1 mg/liter combined chlorine residual required much longer contact time for inactivation. This would allow for more wide-spread distribution of the infectious material. An initial 0.2 mg/liter free chlorine residual was effective against contamination of sewage level of 0.1%, which is not readily noticed. An initial 0.2 mg/liter combined chlorine residual was totally ineffective when sewage contamination level was even as low as 0.01%.

Data reported in this study may be used to estimate the protection afforded by the maintenances of chlorine residuals in water distribution systems. For an initial 0.2 mg/liter free chlorine residual and sewage level of 0.1% approximate bacterial inactivations of 99.9% and viral inactivations of 90% can be expected after 2 hours contact time at pH 8. For an initial 0.2 mg/liter combined chlorine residual, 90% bacterial and 0% viral inactivation would be expected for the same conditions of pH, contact time, and sewage level. With this inactivation information and the assumption of a level of enteric virus, *Salmonella,* and *Shigella* in raw sewage at 1 per ml, (Olivieri *et al.*, 1977), Table 17 was constructed. While the absolute magnitude of microbial inactivation will depend on the factors mentioned at the beginning of this discussion, Table 17 does show that the maintenance of a free chlorine residual will confer considerable protection. The degree of protection afforded by a combined chlorine residual is small, and would only be of value in cases where the levels of introduced contaminant are extremely low.

MUNICIPAL DISTRIBUTION SYSTEM

The water distribution system is not only the most expensive part of a public water supply system but is also the most vulnerable. The enormous pipe surface-to-water volume ratio provides numerous opportunities for defects and surface for chemical and biological activities. Haney (1961) expressed the above ratio in terms of 0.6 to 0.7 acres of pipe surface per 1000 populations served, whereas Larson (1966) indicated that each square foot of pipe surface sees 1 mgd of water.

The Baltimore water distribution sytem is somewhat unique for an Eastern city. A free chlorine residual can be demonstrated in all parts of town and the overwhelming majority of samples collected are of good quality. The water in Frederick water distribution system, on the other hand is treated by different process. At present, a portion of the water for Frederick is an untreated upland surface water that is only chlorinated. To maintain a residual in the transmission line, ammonia is intentionally added. The

TABLE 17. ESTIMATED PATHOGEN INTAKE BY WATER CONSUMERS WHEN TAP WATER WITH NO CHLORINE, 0.2 mg/1 FREE CHLORINE, OR 0.2 mg/1 COMBINED CHLORINE IS CONTAMINATED WITH 0.1% SEWAGE

		Pathogen intake by consumer (2 liters of water/person-day)*		
Enteric Pathogens	Estimated minimum infective dose	with no chlorine	with 0.2 mg/1 free chlorine	with 0.2 mg/1 combined chlorine
virus	1 (Westwood & Sattar, 1976)	2	.2	2
Shigella	10 (Bryan, 1974)	2	.002	.2
Salmonella	10,000 (Bryan, 1974)	2	.002	.2

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*National Academy of Sciences (1977)

water in the Frederick system is generally of good quality but does have high turbidity values and high plate counts at several sampling stations.

Microbiological Quality

Coliform--

986 samples were collected from the municipal water distribution systems (850 from Baltimore and 186 from Frederick). Less than 1% (6 of 850) of the samples from Baltimore contained coliform greater than 2 MPN/100 (4 samples at 2, 1 sample at 6, and 1 sample at 33 MPN/100 ml). Isolates tested from each of these samples did not yield the classical ++-- IMVIC patter for *E. coli* or the characteristic --++ IMVIC pattern for *Enterobacter aerogenes* but rather intermediate patterns of -+-+ and -+++. About 3% (4 of 136) of the samples collected in Frederick were positive for coliforms. The coliform levels were 2, 49, 170 and > 2,400 MPN/100 ml and were collected at the same sampling station. The low number of positive coliform samples in both systems did not permit the expression of any meaningful correlation between presence and level of coliforms and the chlorine residual. It was moreover, noted that chlorine residuals were measured in the water in which samples were positive for coliform.

Bacterial Plate Count--

The bacterial plate count has long been recognized as a useful parameter in water treatment and has been routinely used to evaluate water treatment processes. The bacterial plate count has generally been performed on a relatively rich complex medium and incubated aerobically and thus yielded an estimate of the number of aerobic heterotrophic bacteria. Anaerobic and autotrophic microorganisms will not grow and, therefore, not be enumerated. The bacterial plate count will be influenced by the medium employed. A diluted, weaker medium may yield higher numbers than a richer medium. Victoreen (1977) reported consistently higher plate counts using an 8-fold diluted Standard Methods plate count medium supplemented with iron. In laboratory practices too often conditions of incubation also are not consistent and this makes comparisons and evaluations of bacterial plate count data difficult. Table 18 shows the incubation conditions recommended by various agencies and laboratories in different parts of the world for the bacterial plate count test. Temperatures of 20, 22, 28, 35 and 37°C and incubation times of as long as 9 days and as short as 1 day have been employed. No one plate count method has been universally adopted.

Allen, *et al.* (1976) and Geldreich *et al.* (1978) demonstrated that the presence of high levels of bacteria interferes with the determination of coliforms with the membrance filter procedure. They have suggested that the incubation temperature and time be standardized at 35°C and 48 hours. The rationales for the time and temperature standard have to do with the possible interference of various bacteria with the coliform determination such that the standard plate count does not necessarily reflect the number of microorganisms capable of growth on the medium at optimum condition. Significant alteration of incubation temperature and time does dramatically alter the plate count. At 35°C the plate count increased with time till a plateau was observed at 6 days, while at 20°C the plate count appeared to reach a plateau at 12 to 14 days. (Figure 20). Whether the time or tempera-

TABLE 18. RECOMMENDED OR REPORTED INCUBATION TEMPERATURE AND TIME FOR THE BACTERIAL PLATE COUNT FOR WATER SAMPLES

Source	Temperature °C	Time, days
European Economic Community (1975)	37	2
USEPA (1975)	35	2
German Water Regulations (1975)	20	2
United Kingdom Report #71	37	1
Water Research Center, United Kingdom 1976	22	3
	22	7
Victoreen (1977)	28	7
Standard Methods (1971)	35	1
	20	2
This Report	20	9
	35	4

ture of incubation has any particular significance and whether the plateaus are consistent for other samples and conditions remain to be determined.

In the present state of knowledge the bacterial plate count is believed to have only limited sanitary significance. No relationship between it and diseases transmitted by water has been reported. The bacterial plate count, however, does provide an exceptionally sensitive measure of water treatment operation and changes in water quality in the distribution system. The bacterial plate count may be used as a method to check microbial growth in systems. It may become an increasingly important tool to monitor the condition of activated carbon filters in the treatment of water. Members of genera containing some species pathogenic to man: *Pseudomonas, Flavobacterium* and *Aeromonas* have regularly been isolated from plates for the Standard plate count test. (Allen *et al.*, 1976 and Geldreich *et al.*, 1978). These pathogenic microorganisms are opportunistic in nature and present a health hazard in unique environments or circumstances.

Relationship Between Chemical, Physical and Microbial Parameters--

A linear regression model was utilized to examine the distribution system data for relationships between the physical, chemical and microbiological parameters measured. Plate count data, although of no demonstrable sanitary significance, nevertheless give indications of the microbial quality of distribution system samples. On the other hand, the standard plate count has been used as an overall indicator of drinking water quality by Jeffrey and Singley, (1978). Physical and chemical parameters chosen in this analysis were those that would be expected to have an effect on the microbiological quality, that is, parameters for which a causal relationship can be proposed. In the Baltimore distribution system, significant correlation was found between plate counts (20 and 35°C) and free chlorine concentration, turbidity, and temperature.

Free chlorine is an effective bactericide and viricide, and factors influencing efficiency of disinfection have been well established. (Butterfield, 1945, 1946; Fair and Geyer, 1954). The correlation between log plate count (35 and 20°C) and free chlorine residual, and the strong correlation ($R = -0.62$ and $R = -0.73$) between mean log plate count and free chlorine residual found in this study indicate that a free chlorine residual is effective in controlling the general bacterial population in the Baltimore system. When many samples from many parts of the distribution system were assayed, no evidence could be found for the existence of a substantial population of chlorine resistant microorganisms in spite of recent attention drawn to apparently chlorine resistant coliform and non-coliform bacteria found in water distribution system samples. (Herman, 1978; Knowlton, 1977). Any measurable free chlorine residual was found to reduce the plate count effectively.

Increased levels of plate count microorganisms were found to be associated with increased turbidity. This association may be due to a protective effect, with the colloidal particles shielding microorganisms from the disinfectant (Hoff, 1978), or this may be due to microbial action on the pipe surfaces, resulting in increased turbidity. (Allen, 1977). Thus turbidity may be a cause or an effect of increased bacterial levels. Data obtained in this study were entirely observational, and do not support or refute either hypothesis. The turbidity in the Baltimore system was low, generally less than 1.2 NTU. Even at such low values turbidity was found to be correlated with the plate count. While individual data points showed greater scatter, when mean plate count values to turbidity ranges were considered, R values of 0.73 (35°C plate count) and 0.88 (20°C plate count) were obtained.

An analysis of this type is complicated by the fact that the chemical and physical parameters are correlated with each other. Chlorine concentration showed significant correlation with turbidity and temperature. In order to account for these interactions, a multiple regression model was utilized. Since pH was not found to correlate with any of the microbiological, physical, or other chemical parameters, this information was omitted from the multiple regression step. For the 4 day incubation, 35°C plate count, 22% of the variation in the plate count values ($R^2 = 0.22$) could be attributed to the regression on free chlorine residual. The inclusion of turbidity in the analysis accounted for an additional 6% of the variation ($R^2 = 0.28$). When all three variables were included, (free chlorine, turbidity, and temperature) 32% of the variation ($R^2 = 0.32$) in plate count level could be explained. For the 20°C, 9 day incubation plate count, an R^2 value of 0.41 was obtained when chlorine residual alone was considered. The inclusion of turbidity and temperature only increased this value to 0.44. These R^2 values are significant at the 99% level, but are fairly low since the multiple regression included all the data points as opposed to individual regressions which were done on mean log plate count values as well as individual points.

The Frederick system differs from the Baltimore system in that the surface water supply is treated by the chlorine-ammonia process and does not undergo further treatment. The ammonia addition process results in a relatively high total chlorine residual, with only a slight free chlorine residual. At the levels of combined chlorine observed in the Frederick systems, false positive measurements of free chlorine with the DPD method may occur. (Cooper *et al.*, 1974). The mean log 20°C and 35°C plate counts were found to be more dependent on the free chlorine fraction of the total residual than on the total residual. Although combined chlorine is a bactericide, the combined chlorine residual was not as markedly effective as the free residual in controlling the distribution system bacterial populations.

As in the Baltimore system, increasing turbidity was found to be associated with increased mean log plate count. Since the Frederick City water does not undergo complete treatment, a wider range of turbidities was encountered. Turbidity was not found to correlate with either free or total chlorine residual in the Frederick distribution system.

The regression curves for log plate count versus the midpoints of the ranges of free chlorine residuals for both the Frederick and Baltimore City distribution system samples are shown in Figure 43. These figures were constructed for comparison of the effect of the free residual in the two different systems. The 35°C plate count for the Frederick system samples

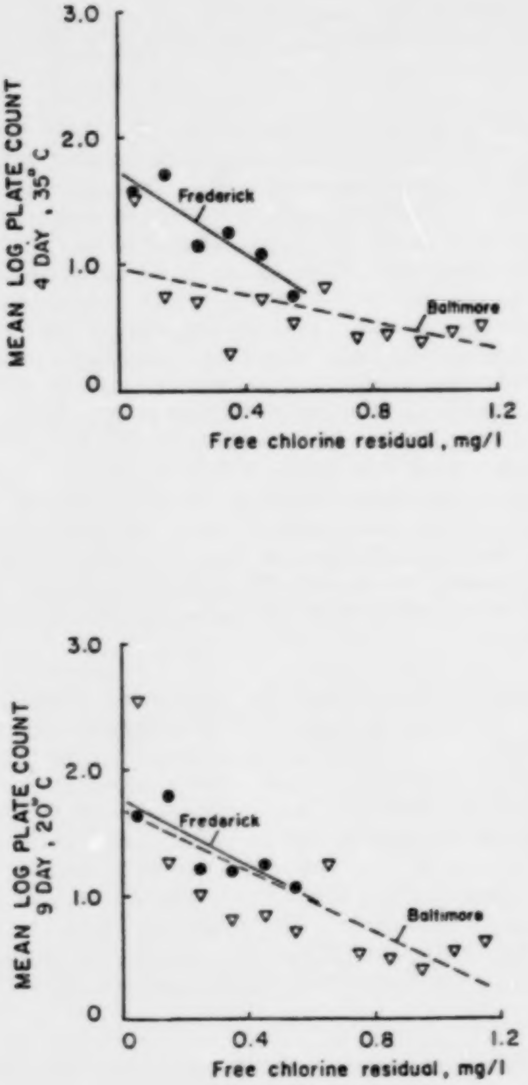

Figure 43. Influence of free chlorine residual on mean log plate counts.

showed a greater dependence on chlorine residual, as evidenced by the larger negative slope, than did the 35°C plate count for the Baltimore system samples. The 20°C plate count showed almost identical slopes in the two systems. The Frederick system maintains a high combined chlorine residual, while the residual in Baltimore is almost entirely of the free form. A similar figure comparing the effect of turbidity on the mean log plate count in the two systems is shown in Figure 44. The increase in mean log plate count with increasing turbidity was similar for the 35°C plate count, but the 20°C plate count responded differently in the two systems, with the plate count in the Baltimore system showing a larger dependence on turbidity. Hoff (1978) stated that " ...the interference of turbidity with disinfection depends much more on the types of turbidity present than the number of turbidity units present".

The maintenance of a free chlorine residual, and control of turbidity are effective methods of reducing the bacterial population in distribution systems. However, a considerable variability exists which is not accounted for by the regression analysis. Other factors, such as nutrients and the inherent variability of biological systems, are also probably important. In addition, different systems may respond to changes in chemical and physical parameters in varying degrees, so that control measures sufficient for one system may not be adequate for another. Generally, the maintenance of a free chlorine residual, even a low level residual, was found to be the single most effective control measure.

Microbial Differentiation

A portion of this study was directed to obtain some information on the groups of microorganisms recovered from the bacterial plate count test and to evaluate changes in bacterial populations under different conditions found in the distribution system. Unfortunately the taxonomy of the microbial populations in water recovered on bacterial plates is today unclear and confused. It has not received the same degree of attention naturally as the microbial families and genera of medical importance. Methods employed in this study were not intended to yield firm identification but rather were intended to group the microorganisms and to evaluate their population dynamics.

Despite the variability in the groups of organisms between sampling station and samples and some minor differences in diversity, the overwhelming majority of the greater than 6000 isolates collected in this study was Gram negative non-saccharolytic rod-shaped bacteria. The majority of microorganisms of this category was obligate aerobes but significant numbers of facultative bacteria were observed. It should be noted that strict anaerobic bacteria were selectively excluded by the choice of the method for the plate count. Both the aerobic and facultative groups contained a large percentage of microorganisms that yielded pigmented colonies. The biochemical characteristics of the aerobic group are consistent with the members of the family *Pseudomodaceae* and the genera *Flavobacterium, Alcaligenes* and *Moraxella,* and those of the facultative groups are consistent with members of the genera *Flavobacterium*. These same microorganisms have been reported in water distribution systems from other parts of the country. (Allen *et*

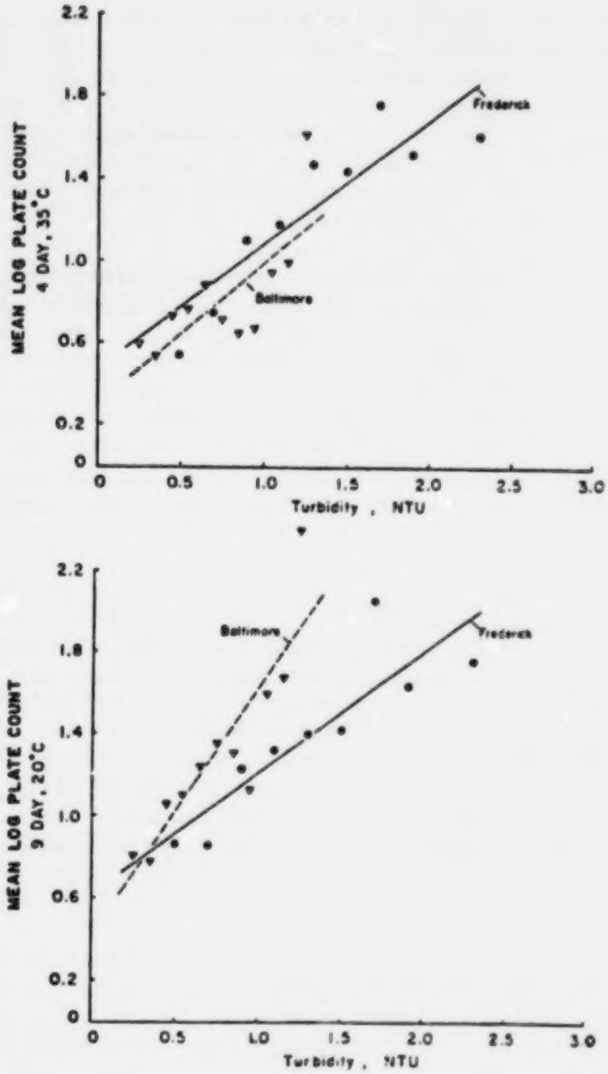

Figure 44. Influence of turbidity on mean log plate counts.

al., 1976; Geldreich *et al.*, 1978). In this study, two distribution systems 50 miles apart, one with water treated by coagulation, sedimentation and sand filtration and other without and having different chlorine residual practices yielded similar predominant groups of microorganisms.

Little microbial diversity was observed at majority of the sampling stations. Several groups made up the major portion of the microorganisms recovered, and the same groups of microorganisms were found at each station. Station 1 (Frederick) and Station 44 (Baltimore) were exceptions, and groups of microorganisms observed there were more diverse than at other stations. Eight and 10 additional groups of microorganisms were found over the major groups. While the 20°C incubation temperature consistently yielded higher plate counts than the 35°C incubation temperatures, particularly in samples from the Baltimore distribution system, the bacterial groups recovered from sample by stations at the different incubation temperatures were also similar. However, group 10 (possible *Aeromanas*) and groups 13 and 16 (possible *Enterbacteriaceae, Bacillus* and/or *Staphylococci*) were found almost exclusively at 35°C at station 1, 4, 27, 44 and 48.

Unfortunately, little data on the distribution of microorganisms in water transmission lines were available for comparison. The same general groups of microorganisms have been reported in other systems. The similarity between microorganisms found at the 20°C and 35°C plate counts was surprising. An explanation for the lack of major shifts of population from station to station and for different incubation temperatures would be speculation without further indepth study. Only 6 stations in Baltimore and 2 stations in Frederick were studied in detail. The predominant bacterial groups were most probably selected by the restrictive conditions of nutrients and by their ability to resist the disinfectant residuals, and further by the methods employed in their recovery and enumeration.

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APPENDIX A. HOLDING TANK DATA

TABLE A-1. BACTERIAL INACTIVATION, HOLDING TANK STUDIES, pH 8.0, 0.69 to 1.25 mg/l INITIAL FREE CHLORINE

Run #	Temp °C	% Autoclaved Sewage	Cl Bkpt mg/l	Chlorine Residual, mg/l						Coliform, log N/N_o				*S. typhimurium* log N/N_o				*S. sonnei* log N/N_o			
				0 Time		2 minutes		120 minutes		2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.
				Free	Total	Free	Total	Free	Total												
20	0	1	150	.69	.90	.02	.69	0	.65	-2.2	<-2.9	<-2.9	<-2.9	<-2.9	<-2.9	<-2.9	<-2.9	-2.2	<-3.1	<-3.1	<-3.1
		5		.69	.90	0	.54	0	.51	0	-.3	-.2	-.1	0	-.3	-.3	-.4	0	-.4	-.3	-.3
		10		.69	.90	0	.35	0	.32	.2	-.1	0	-.1	.2	-.1	-.1	-.2	.2	-.2	-.2	-.1
		10		0	0	0	0	0	0	.3	-.2	-.2	-.1	.2	-.1	-.1	.2	.2	-.2	-.1	0
30	10	1	220	1.21	1.39	.05	.95	.01	.91	-.5	-1.6	-2.4	-3.2	-.6	-1.8	<-3.4	<-3.4	-.6	-2.7	-3.1	<-3.3
		5		1.21	1.39	.01	.50	0	.46	-.1	-.2	-.1	-.8	-.2	-.2	-.2	-.6	-.1	-.2	-.2	-.4
		10		1.21	1.39	0	.24	0	.19	-.3	0	-.2	-.1	-.2	0	.1	0	0	-.1	0	.1
		10		0	0	0	0	0	0	-.1	-.2	-.1	.2	-.1	0	-.1	.2	0	.1	-.2	.1
23	20	1	150	.92	1.13	.03	.78	.02	.71	-2.4	<-2.9	<-2.9	<-2.9	-2.1	<-2.9	<-2.9	<-2.9	2.4	<-2.8	<-2.8	<-2.8
		5		.92	1.13	.02	.55	.01	.55	-.1	-.3	-.8	-2.0	-.1	-.3	-1.0	-3.1	-.2	-.5	-1.2	-3.5
		10		.92	1.13	0	.45	0	.38	0	-.2	-.4	-1.0	0	-.1	-.4	-1.3	0	-.3	-.4	-1.7
		10		0	0	0	0	0	0	.3	0	-.2	-.2	.3	0	-.3	-.1	0	-.1	.3	-.2
32	30	1	220	1.25	1.45	.03	.83	.03	.76	-.5	<-3.2	<-3.2	<-3.2	-.8	<-3.3	<-3.3	<-3.3	-.8	<-3.3	<-3.3	<-3.3
		5		1.25	1.45	.01	.30	.01	.30	-.1	-.2	-1.5	-2.7	-.2	-.4	-.5	<-4.0	-.1	-.4	-1.6	<-4.0
		10		1.25	1.45	0	.08	0	.03	.1	0	-.2	0	.1	.1	-.2	.1	-.2	-.1	-.3	0
		10		0	0	0	0	0	0	-.1	-.2	.2	0	-.2	-.1	.3	-.1	-.1	-.2	.2	-.1

TABLE A-2. VIRAL INACTIVATION, HOLDING TANK STUDIES, pH 8.0, 0.69 to 1.25 mg/1 INITIAL FREE CHLORINE

Run #	% Autoclaved Sewage	f2, log N/N_o				polio 1, log N/N_o			
		2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.
20	1	-.4	-.5	-.5	-.5	-1.0	-1.0	-1.4	-1.7
	5	-.2	0	0	-.2	.1	-.3	-.7	-.7
	10	-.1	-.1	0	0				
	10	0	-.1	0	0	0	.2	-.3	-.1
30	1	-.3	-.5	-.4	-.3	-.8	-1.8	<-2.7	<-2.7
	5	-.1	-.1	-.1	-.1	.1	-.1	-.8	-1.1
	10	-.1	-.1	-.1	-.1				
	10	-.1	0	0	0	.1	-.5	-.2	.2
23	1	-.9	-1.0	-1.1	-1.6				
	5	-.3	-.2	0	0				
	10	-.1	0	-.2	-.1				
	10	0	.1	0	-.1				
32	1	-.2	-.4	-.7	-.8				
	5	0	-.1	-.1	-.4				
	10	.1	-.1	-.1	0				
	10	.1	-.1	0	0				

TABLE A-3. BACTERIAL INACTIVATION, HOLDING TANK STUDIES, pH 8.0, 0.90 to 1.25 mg/1 INITIAL COMBINED CHLORINE

Run #	Temp °C	% Autoclaved Sewage	Cl Bkpt mg/l	Chlorine Residual, mg/l						Coliform, log N/N₀				*S. typhimurium* log N/N₀				*S. sonnei* log N/N₀			
				0 Time		2 minutes		120 minutes		2	30	60	120	2	30	60	120	2	30	60	120
				Free	Total	Free	Total	Free	Total	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.	min.
11	0	1	270	0	.99	0	.85	0	.80	.1	0	-.1	-.2	0	-.2	-.3	-.2	-.1	-.2	-.5	-1.1
		5		0	.99	0	.58	0	.49	0	0	-.2	-.1	0	-.1	-.3	-.2	.2	-.2	-.9	-1.2
		10		0	.99	0	.38	0	.25	.2	-.1	-.1	-.1	0	-.3	-.2	-.1	0	-.2	-.2	-.4
		11		0	0	0	0	0	0	0	.1	-.1	-.1	0	0	-.1	0	0	.1	-.1	-.1
20	0	1	150	0	.90	0	.83	0	.80	-.2	-.2	-.5	-1.1	-.2	-.7	-.8	-1.3	-.2	-.4	-.8	-1.5
		5		0	.90	0	.65	0	.63	.2	0	-.1	-.3	.2	0	-.4	-.4	.1	0	-.1	-.6
		10		0	.90	0	.51	0	.47	.2	-.1	-.1	-.1	.3	-.1	-.2	-.2	.1	-.1	-.1	-.2
		10		0	0	0	0	0	0	.3	-.2	-.2	-.1	.2	-.1	-.1	.2	.2	-.2	-.1	0
2	10	1	230	0	1.19	0	.87	0	.87	.3	-.6	-1.1	-2.0	-.1	-.7	-1.2	<-2.3	0	-.3	-1.1	-1.9
		5		0	1.19	0	.61	0	.46	.1	-.3	-.7	-1.5	0	-.3	-.7	-1.6	0	-.2	-.9	-1.5
				0	0	0	0	0	0	0	.1	0	-.1	0	.1	-.1	-.1	-.2	.2	-.1	0
6	20	1	230	0	1.25	0	1.06	0	1.04	-.1	-1.7	-2.7	<-2.7	0	-.9	-2.6	<-2.9	0	-1.6	<-2.9	<-2.9
		5		0	1.25	0	.80	0	.71	-.1	-.7	-1.4	-2.4	.1	-.2	-1.0	-2.6	.2	-.7	-1.5	-3.6
		10		0	1.25	0	.27	0	.39	0	-.3	-.9	-1.7	.1	-.1	-.2	-1.0	.2	-.1	-.9	-2.1
		11		0	0	0	0	0	0	0	0	0	0	0	.1	0	0	0	0	0	0
23	20	1	150	0	1.13	0	.97	0	.93	-.1	-1.0	-1.8	<-2.9	0	-1.4	-2.3	<-2.9	-.1	-1.4	<-2.8	<-2.8
		5		0	1.13	0	.81	0	.76	.1	-.7	-1.0	-1.7	.1	-.2	-1.5	-2.7	.1	-.6	-2.2	<-3.5
		10		0	1.13	0	.59	0	.57	.2	-.5	-.9	-1.2	.1	-.3	-1.1	-2.2	.3	-.4	-1.7	--
		10		0	0	0	0	0	0	.3	0	-.2	-.2	.3	0	-.3	-.1	0	-.1	.3	-.2
7	10	1	270	0	1.16	0	1.00	0	.87	.5	--	<-2.5	<-2.5	-.5	-1.6	<-3.1	<-3.1	-.5	<-2.9	<-2.9	<-2.9
		5		0	1.16	0	.61	0	.48	.4	-1.3	<-3.2	<-3.2	-.3	-1.0	-3.8	<-3.8	-.3	-1.6	-3.0	<-3.6
		10		0	1.16	0	.37	0	.25	0	-.2	-.5	--	0	-.3	-.5	-.8	.1	-.1	-.3	--
		11		0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--
9	10	1	270	0	.90	0	.71	0	.66	-.4	--	<-2.8	<-2.8	-.2	-.8	-3.3	<-3.3	-.3	--	<-2.8	<-2.8
		5		0	.90	0	.42	0	.30	0	-.6	-2.5	-3.5	0	-.2	-.8	<-4.0	.1	-.5	--	<-3.5
		10		0	.90	0	.16	0	.10	-.1	-.1	0	0	-.2	-.1	-.2	-.1	0	0	0	-.1
		11		0	0	0	0	0	0	--	--	--	--	--	--	--	--	--	--	--	--

TABLE A-4. VIRAL INACTIVATION, HOLDING TANK STUDIES, pH 8.0
0.90 to 1.25 mg/1 INITIAL COMBINED CHLORINE

Run #	% Autoclaved Sewage	f2 log N/N_o 2 min.	30 min.	60 min.	120 min.	polio 1 log N/N_o 2 min.	30 min.	60 min.	120 min.
11	1	0	0	0	-.1				
	5	-.2	0	.1	-.1				
	10	0	0	0	0				
	11	-.1	-.1	.1	.1				
20	1	0	-.1	-.1	-.1	-.3	-.9	-.7	-.8
	5	0	-.1	0	-.1	-.1	-.2	-1.0	-.8
	10	0	0	-.1	-.1				
	10	0	-.1	0	0	0	.2	-.3	-.1
2	1	-.2	-.1	-.1	-.2				
	5	0	0	-.1	0				
		-.7	.4	-.6	.1				
6	1	-.1	-.3	-.3	-.5	0	-1.2	-1.6	-1.6
	5	-.1	-.2	--	-.4				
	10	.1	-.2	-.2	-.3				
	11	0	0	0	0	-.2	0	.1	0
23	1	-.1	-.1	-.1	-.1				
	5	-.2	-.1	-.2	-.1				
	10	-.1	0	-.1	-.1				
	10	0	.1	0	-.1				
7	1	0	0	-.4	-.7	-.3	-1.7	-1.7	-2.2
	5	-.2	-.1	0	-.3	-.3	-1.5	-1.9	-1.8
	10	0	-.1	-.1	-.3				
	11	0	-.1	.1	0	0	-.1	0	.1
9	1	0	-.2	-.4	-.4	0	-1.9	-2.0	-1.9
	5	0	-.1	-.1	-.2	-.3	-1.2	-1.7	-1.9
	10	-.1	0	0	0				
	11	0	0	.1	0	0	0	.1	0

TABLE A-5. BACTERIAL INACTIVATION, HOLDING TANK STUDIES, pH 8.0, 0.21 to 0.26 mg/l INITIAL FREE CHLORINE

Run #	Temp °C	% Autoclaved Sewage	Bkpt mg/l	Chlorine Residual, mg/l						Coliform, log N/N_0				*S. typhimurium*, log N/N_0				*S. sonnei*, log N/N_0			
				0 Time		2 minutes		120 minutes		2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.
				Free	Total	Free	Total	Free	Total												
26	0	.10	150	.23	.35	.03	.23	.01	.21	.1	-.8	-1.1	-1.5	-.8	-2.2	-2.3	-2.8	0	-2.2	<-3.2	<-3.2
		.20		.23	.35	.02	.22	0	.20	.1	-.1	-.4	-.5	-.2	-1.0	-1.6	-1.6	-.1	-.7	-1.3	-2.5
		.50		.23	.35	.01	.21	0	.21	-.1	-.2	-.2	-.2	-.4	-1.1	-1.2	-1.6	0	-.4	-.9	-1.9
		.10		0	0	0	0	0	0	-.1	0	.1	0	0	0	.1	-.1	0	-.1	.1	0
28	0	.10	150	.21	.34	.05	.24	.03	.23	-1.3	<-3.4	<-3.4	<-3.4	-1.6	<-3.5	<-3.5	<-3.5	-.9	<-3.2	<-3.2	<-3.2
		.20		.21	.34	.03	.24	.02	.23	-.5	<-3.7	<-3.7	<-3.7	-.9	<-3.8	<-3.6	<-3.8	-.4	<-3.5	<-3.5	<-3.5
		.50		.21	.34	.02	.22	.01	.21	-.2	-.1	-.3	-.6	-.4	-.8	-1.0	-1.3	-.4	-.5	-.9	-1.3
		.10		0	0	0	0	0	0	-.1	.1	-.1	0	-.2	0	0	.3	-.2	.2	.1	0
31	10	.10	220	.26	.37	.05	.23	.01	.21	-.4	-1.8	-2.5	<-3.7	-.5	-1.4	-1.5	-2.2	-1.4	-1.8	<-3.5	<-3.5
		.20		.26	.37	.05	.22	.01	.20	-.3	-.3	-.3	-.8	-.4	-.5	-.6	-1.0	-.3	-.4	-.5	-1.2
		.50		.26	.37	.02	.18	.01	.17	.1	-.1	.1	0	0	-.2	-.1	-.4	-.1	0	-.1	-.2
25	20	.10	150	.25	.37	.03	.22	.02	.20	-3.3	<-3.7	<-3.7	<-3.7	-2.3	<-3.6	<-3.6	<-3.6	-3.5	<-3.6	<-3.6	<-3.6
		.50		.25	.37	.02	.23	.01	.19	-.3	-.7	-.9	-2.2	-.3	-.9	-1.4	-2.3	-.5	-.8	-1.4	--
		1.00		.25	.37	0	.22	0	.18	-.2	-.2	-.2	-.2	-.2	-.1	-.3	-.7	-.3	-.3	-.4	-.6
		.10		0	0	0	0	0	0	.2	-.1	-.2	.1	.2	0	-.3	.1	.1	.1	-.4	.1

TABLE A-6. VIRAL INACTIVATION, HOLDING TANK STUDIES, pH 8.0, 0.21 to 0.26 mg/l INITIAL FREE CHLORINE

Run #	% Autoclaved Sewage	f2, log N/N_o 2 min.	30 min.	60 min.	120 min.	polio 1, log N/N_o 2 min.	30 min.	60 min.	120 min.
26	.10	-.4	-.8	-.8	-.8	-.5	-1.6	-1.9	-1.8
	.20	-.3	-.3	-.3	-.3	-.3	-1.5	-1.3	-1.5
	.50	-.3	-.4	-.3	-.4				
	.10	0	0	0	0	.1	0	.1	-.1
28	.10	-.3	-2.0	<-2.4	<-2.4				
	.20	-.2	-.7	-.9	-1.0				
	.50	-.2	0	-.2	-.2				
	.10	0	0	-.1	.1				
31	.10	-.4	-.6	-.5	-.6	-.5	-1.3	-1.8	-1.6
	.20	-.2	-.4	-.4	-.4	-.4	-1.3	-1.4	-1.4
	.50	-.6	-.5	-.5	-.6				
25	.10	-.6	<-2.6	<-2.6	<-2.6				
	.50	-.1	-.2	-.2	-.2				
	1.00	.1	0	0	-.1				
	.10	0	0	0	0				

TABLE A-7. BACTERIAL INACTIVATION, HOLDING TANK STUDIES, pH 8.0, 0.23 to 0.37 mg/1 INITIAL COMBINED CHLORINE

Run #	Temp °C	% Autoclaved Sewage	Bkpt mg/1	Chlorine Residual, mg/1 0 Time Free	0 Time Total	2 minutes Free	2 minutes Total	120 minutes Free	120 minutes Total	Coliform, log N/N_0 2 min.	30 min.	60 min.	120 min.	*S. typhimurium*, log N/N_0 2 min.	30 min.	60 min.	120 min.	*S. sonnei*, log N/N_0 2 min.	30 min.	60 min.	120 min.
26	0	.01	150	0	.35	0	.33	0	.31	-.1	-.1	-.1	-.2	-.1	0	-.1	-.5	-.2	-.1	-.2	-.5
		.05		0	.35	0	.30	0	.30	-.1	-.1	-.2	-.2	-.1	-.2	-.3	-.4	-.2	-.3	-.2	-.4
		.10		0	.35	0	.30	0	.30	0	-.3	-.1	-.2	-.1	-.4	-.1	-.2	-.1	-.5	-.5	-1.0
		.10		0	0	0	0	0	0	-.1	0	.1	0	0	0	.1	-.1	0	-.1	.1	0
28	0	.01	150	0	.34	0	.30	0	.29	0	0	0	-.1	.1	.1	.1	.1	.2	-.2	.2	.1
		.05		0	.34	0	.30	0	.29	-.1	0	-.1	-.1	0	.1	0	-.1	-.1	-.2	0	-.3
		.10		0	.34	0	.30	0	.29	-.1	.1	.1	-.1	.2	.1	.1	.1	.2	.1	.2	-.2
		.10		0	0	0	0	0	0	-.1	.1	-.1	0	-.2	0	0	.3	-.2	.2	.1	0
5	20	.01	230	0	.23	0	.22	0	.20	-.1	0	-.2	-1.1	0	0	-.1	-.9	0	0	-.1	-1.0
		.05		0	.23	0	.21	0	.20	-.1	-.1	-.2	-1.0	0	-.1	-.3	-.7	0	0	-.2	-.9
		.10		0	.23	0	.20	0	.20	-.4	0	-.2	-1.1	-.1	0	--	-.8	0	.1	--	-.9
		.125		0	0	0	0	0	0	0	0	0	0	.1	.1	-.1	-.1	.1	0	.1	-.2
25	20	.01	150	0	.37	0	.34	0	.32	-.5	-.6	-.8	-1.8	-.4	-.5	-1.1	-2.7	-.4	-.7	-1.1	-3.1
		.05		0	.37	0	.33	0	.31	-.2	-.5	-.6	-1.9	-.2	-.4	-1.0	-2.0	-.1	-.6	-.7	-2.6
		.10		0	.37	0	.33	0	.31	-.2	-.2	-.9	-1.8	-.2	-.2	-1.3	-2.6	0	-.5	-1.2	-2.5
		.10		0	0	0	0	0	0	.2	-.1	-.2	.1	.2	0	-.3	.1	.1	.1	-.4	.1
8	30	.01	270	0	.27	0	.25	0	.23	.2	-.1	-.9	-1.7	.3	.1	-.2	-2.3	0	-.2	-.7	-2.0
		.05		0	.27	0	.23	0	.21	-.1	0	-.6	-1.3	-.1	.1	-.1	-1.0	-.2	-.1	-.8	-2.0
		.10		0	.27	0	.24	0	.20	-.1	-.2	-.7	-1.7	0	0	-.2	-2.2	.1	-.2	-.8	-2.0
		.125		0	0	0	0	0	0	0	.1	.1	-.1	0	0	.1	-.1	-.1	0	-.1	0

TABLE A-8. VIRAL INACTIVATION, HOLDING TANK STUDIES, pH 8.0, 0.23 to 0.37 mg/l INITIAL COMBINED CHLORINE

Run #	% Autoclaved Sewage	f2, log N/N_o 2 min.	30 min.	60 min.	120 min.	polio 1, log N/N_o 2 min.	30 min.	60 min.	120 min.
26	.01	0	0	-.2	-.1	-.5	-.5	-1.0	-1.0
	.05	-.1	-.1	-.1	-.1	-.3	-.4	-.7	-.9
	.10	0	0	-.1	0				
	.10	0	0	0	0	.1	0	.1	-.1
28	.01	.1	-.2	-.2	.1				
	.05	.2	0	0	-.1				
	.10	.1	0	-.1	.1				
	.10	0	0	-.1	.1				
5	.01	0	-.1	-.2	-.4				
	.05	.1	-.1	-.3	-.3				
	.10	0	-.1	-.2	-.4				
	.125	-.1	0	-.1	.1				
25	.01	0	-.1	-.2	-.4				
	.05	0	-.1	-.1	-.2				
	.10	0	0	-.1	-.1				
	.10	0	0	0	0				
8	.01	-.1	0	-.1	-.2				
	.05	-.1	0	-.2	-.3				
	.10	0	0	-.2	-.3				
	.125	-.1	.1	0	-.1				

TABLE A-9. BACTERIAL INACTIVATION, HOLDING TANK STUDIES, pH 6.0, 0.75 to 1.26 mg/l INITIAL FREE CHLORINE

Run #	Temp °C	Autoclaved Sewage	Bkpt mg/l	Chlorine Residual, mg/l						Coliform, log N/N_o				*S. typhimurium*, log N/N_o				*S. sonnei*, log N/N_o			
				0 Time Free	0 Time Total	2 minutes Free	2 minutes Total	120 minutes Free	120 minutes Total	2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.
19	0	1	150	.75	.91	.06	.64	.02	.60	<-3.1	<-3.1	<-3.1	<-3.1	<-3.2	<-3.2	<-3.2	<-3.2	<-3.1	<-3.1	<-3.1	<-3.1
		5		.75	.91	.02	.47	0	.41	-2.8	<-3.8	<-3.8	<-3.8	-2.8	-3.7	<-3.8	<-3.8	-3.4	<-3.8	<-3.8	<-3.8
		10		.75	.91	0	.30	0	.23	-.3	-.6	-.7	-1.2	-.5	-.8	-.8	-1.2	-.4	-.7	-.9	-1.3
		10		0	0	0	0	0	0	.2	-.1	-.2	.1	.2	0	-.4	.1	.1	0	-.3	.2
14	10	1	270	.91	1.07	--	.75	0	.71	<-2.6	<-2.6	<-2.6	<-2.6	<-3.0	<-3.0	<-3.0	<-3.0	<-2.8	<-2.8	<-2.8	<-2.8
		5		.91	1.07	0	.51	0	.38	-3.1	<-3.3	<-3.3	<-3.3	-3.4	-3.4	<-3.7	<-3.7	-3.2	<-3.5	<-3.5	<-3.5
		5		0	0	0	0	0	0	0	.1	-.1	0	-.1	0	.1	0	-.2	0	.1	0
30	10	1	220	1.26	1.45	.09	1.01	.05	.93	<-3.3	<-3.3	<-3.3	<-3.3	<-3.3	<-3.3	<-3.3	<-3.3	<-3.4	<-3.4	<-3.4	<-3.4
		5		1.26	1.45	.03	.59	.01	.49	-3.7	<-4.0	<-4.0	<-4.0	-2.5	-3.3	-4.0	<-4.0	-3.8	<-4.1	<-4.1	<-4.1
		10		1.26	1.45	.01	.24	0	.14	-.4	-.6	-.6	-.7	-.3	-.6	-.4	-.5	-.4	-.6	-.7	.9
		10		0	0	0	0	0	0	-.2	0	.1	.1	-.1	-.1	.1	0	-.1	-.1	0	.1
22	20	1	150	.92	1.15	.06	.83	.02	.74	<-3.0	<-3.0	<-3.0	<-3.0	<-3.2	<-3.2	<-3.2	<-3.2	<-3.1	<-3.1	<-3.1	<-3.1
		5		.92	1.15	0	.58	0	.46	-2.7	<-3.7	<-3.7	<-3.7	-2.6	<-3.8	<-3.8	<-3.8	-3.0	<-3.8	<-3.8	<-3.8
		10		.92	1.15	0	.34	0	.23	-.4	-.9	-2.6	<-4.0	-.4	-.7	-1.2	-3.6	-.4	-.9	--	<-4.1
				0	0	0	0	0	0	.2	-.2	-.2	.1	.2	-.3	-.3	.1	.1	-.1	-.1	.1
12	30	1	220	1.26	1.45	.03	.91	.03	.86	<-3.2	<-3.2	<-3.2	<-3.2	<-3.3	<-3.3	<-3.3	<-3.3	<-3.4	<-3.4	<-3.4	<-3.4
		5		1.26	1.45	0	.35	--	.29	-.6	-3.6	<-3.9	<-3.9	.6	-3.0	<-4.0	<-4.0	-.8	<-4.1	<-4.1	<-4.1
		10		1.26	1.45	0	.08	0	.04	-.4	-.4	-.4	-.3	-.5	-.4	-.3	-.3	-.5	-.5	-.4	-.3
		10		0	0	0	0	0	0	0	-.1	0	.1	.1	0	0	0	-.3	-.1	.2	.1

TABLE A-10. VIRAL INACTIVATION, HOLDING TANK STUDIES, pH 6.0, 0.75 to 1.26 mg/l INITIAL FREE CHLORINE

Run #	% Autoclaved Sewage	f2, log N/N_o				polio 1, log N/N_o			
		2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.
19	1	-1.0	-1.6	-1.6	-2.1	-1.7	-2.7	-3.5	<-3.8
	5	-.6	-.6	-.7	-.7	-.8	-.7	-.7	-.8
	10	-.3	-.3	-.2	-.3				
	10	.1	0	.1	0	.1	-.1	-.1	0
14	1	-1.5	-2.1	-2.1	-2.1	-1.5	-3.2	-3.5	-3.5
	5	-1.0	-.9	-.9	-.9				
	5	0	-.1	.1	.1	-.3	0	0	.2
30	1	-2.6	<-2.6	<-2.6	<-2.6	-2.3	<-2.7	--	<-2.7
	5	-.8	-.8	-.9	-.9	-.6	-1.7	-1.8	<-2.7
	10	-.3	-.3	-.3	-.5				
	10	0	.1	-.1	0	0	-.5	.2	.1
22	1	-2.0	<-2.9	<-2.9	<-2.9				
	5	-.8	-1.2	-.8	-.9				
	10	-.3	-.5	-.3	-.3				
		0	0	0	0				
32	1	-1.7	-2.6	--	--				
	5	-.4	-.7	-.9	-1.1				
	10	-.1	-.3	-.4	-.3				
	10	0	.1	-.1	0				

TABLE A-11. BACTERIAL INACTIVATION, HOLDING TANK STUDIES, pH 6.0, 0.88 to 1.25 mg/1 INITIAL COMBINED CHLORINE

Run #	Temp °C	% Autoclaved Sewage	Mkpt mg/1	Chlorine Residual, mg/1 0 Time Free	0 Time Total	2 minutes Free	2 minutes Total	120 minutes Free	120 minutes Total	Coliform, log N/N_o 2 min.	30 min.	60 min.	120 min.	*S. typhimurium*, log N/N_o 2 min.	30 min.	60 min.	120 min.	*S. sonnei*, log N/N_o 2 min.	30 min.	60 min.	120 min.
11	0	1	270	0	.99	0	.87	0	.86	-.1	-.6	-1.1	-2.7	.1	-.1	-.8	-2.6	.2	-.8	<-2.4	<-2.4
		5		0	.99	0	.58	0	.48	.2	-.1	-.6	-1.1	.1	0	-.4	-.8	.2	-.7	-.7	--
		10		0	.99	0	.30	0	.18	.2	.1	-.2	-.2	.1	-.1	-.2	-.2	.1	-.3	-.6	-.6
		11		0	0	0	0	0	0	.1	0	-.1	-.1	.2	0	-.1	-.1	.3	0	-.2	-.1
19	0	1	150	0	.88	0	.82	0	.79	.1	-1.8	-2.8	<-3.1	-.2	-1.4	-2.6	<-3.2	0	-2.3	<-3.1	<-3.1
		5		0	.88	0	.70	0	.63	.1	-.6	-2.0	<-3.8	0	-.8	-1.6	<-3.8	0	-1.0	-2.9	<-3.8
		10		0	.88	0	.53	0	.47	-.2	-.6	-1.2	-3.1	-.3	-.9	-1.3	-3.0	-.2	-.7	-1.7	<-4.1
		11		0	0	0	0	0	0	.2	-.1	-.2	.1	.2	0	-.4	.1	.1	0	-.3	.2
2	10	1	230	0	1.19	0	1.06	0	.93	-.1	<-2.3	<-2.3	<-2.3	0	<-2.5	<-2.5	<-2.5	0	<-2.9	<-2.9	<-2.9
		5		0	1.19	0	.75	0	.55	-.1	-2.1	<-3.0	<-3.0	.1	-2.0	<-3.2	<-3.2	.1	-2.2	<-3.5	<-3.5
		11		0	0	0	0	0	0	.1	0	-.1	0	0	0	0	0	0	-.1	.1	0
14	10	1	270	0	1.07	0	.94	0	.90	.1	-1.6	<-2.6	<-2.6	0	-2.1	<-3.0	<-3.0	0	<-2.8	<-2.8	<-2.8
		5		0	1.07	0	.61	0	.54	.1	-1.0	-2.6	<-3.3	.2	-.9	-2.6	<-3.7	0	--	<-3.5	<-3.5
		5		0	0	0	0	0	0	0	.1	-.1	0	-.1	0	.1	0	-.2	0	.1	0
6	20	1	230	0	1.25	0	1.02	0	.58	0	-2.2	<-2.7	<-2.7	0	-2.4	<-2.9	<-2.9	.1	<-3.0	<-3.0	<-3.0
		5		0	1.25	0	.80	0	.48	-.1	-2.1	<-3.4	<-3.4	0	-1.5	<-3.6	<-3.6	0	<-3.7	<-3.7	<-3.7
		10		0	1.25	0	.49	0	.32	0	--	-1.7	-2.7	-.1	--	-.7	-2.2	-.1	--	-1.5	-2.7
		11		0	0	0	0	0	0	0	0	0	0	0	.1	0	.2	0	0	0	-.2
22	20	1	150	0	1.15	0	1.01	0	1.00	-.2	<-3.0	<-3.0	<-3.0	-.1	<-3.2	<-3.2	<-3.2	0	<-3.1	<-3.1	<-3.1
		5		0	1.15	0	.86	0	.76	0	<-3.7	<-3.7	<-3.7	0	-3.5	<-3.8	<-3.8	0	-3.4	<-3.8	<-3.8
		10		0	1.15	0	.66	0	.50	.1	-3.4	<-4.0	<-4.0	0	-2.4	-4.0	<-4.1	-.1	-3.5	<-4.1	<-4.1
		10		0	0	0	0	0	0	.2	-.2	-.2	.1	.2	-.3	-.3	.1	.1	-.1	-.1	.1
7	30	1	270	0	1.16	0	1.05	0	.88	-.4	<-2.5	<-2.5	<-2.5	0.1	<-3.1	<-3.1	<-3.1	-.4	<-2.9	<-2.9	<-2.9
		5		0	1.16	0	.66	0	.52	-.4	-2.2	<-3.2	<-3.2	-.1	-1.0	-3.5	<-3.8	-.1	--	<-3.6	<-3.6
		10		0	1.16	0	.17	0	.12	-.2	-.2	-.4	--	-.1	-.1	-.4	-.9	-.1	-.2	-1.5	--
		11		0	0	0	0	0	0	-.1	0	.1	.1	-.2	0	.1	0	-.2	0	.1	.1
9	30	1	270	0	.90	0	--	0	.78	0	<-2.8	<-2.8	<-2.8	0	<-3.3	<-3.3	<-3.3	0	<-2.8	<-2.8	<-2.8
		5		0	.90	0	.42	0	.27	0	-.5	<-3.5	<-3.5	-.1	-.2	-1.2	<-4.0	.1	-1.9	<-3.5	<-3.5
		10		0	.90	0	.12	0	.05	.2	.1	0	0	0	-.1	-.1	-.2	.2	.1	.1	0
		11		0	0	0	0	0	0	-.1	0	0	.1	0	0	0	.1	-.1	.1	0	-.1

TABLE A-12. VIRAL INACTIVATION, HOLDING TANK STUDIES, pH 6.0, 0.88 to 1.25 mg/l INITIAL COMBINED CHLORINE

Run #	% Autoclaved Sewage	f2, log N/N_o 2 min.	30 min.	60 min.	120 min.	polio 1, log N/N_o 2 min.	30 min.	60 min.	120 min.
11	1	-.3	-.2	-.2	-.4				
	5	-.1	-.1	-.1	-.2				
	10	0	-.1	0	-.1				
	11	0	-.1	.1	.1				
19	1	0	-.1	-.1	-.1	-1.0	-.9	-1.6	-1.5
	5	0	0	0	-.2	-.2	-.1	-1.1	-1.2
	10	.1	0	0	-.1				
		.1	0	.1	0	.1	-.1	-.1	0
2	1	-.1	-.1	-.2	-.2				
	5	-.1	-.1	-.1	-.2				
	11	-.8	.3	-.7	.2				
14	1	-.2	-.3	-.3	-.3	-.4	-1.2	-1.2	-1.8
	5	-.2	-.3	-.3	-.3				
	5	0	-.1	.1	.1	-.3	0	0	.2
6	1	-.2	-.3	-.5	-.9	-.9	-2.1	<-2.6	<-2.6
	5	-.1	-.2	-.4	-.6				
	10	-.1	-.2	-.2	-.5				
	11	0	.1	0	0	-.1	0	0	.1
22	1	-.4	-.7	-.4	-.5				
	5	-.5	-.2	-.3	-.5				
	10	-.6	-.2	-.2	-.4				
	10	0	0	0	0				
7	1	-.2	-.4	-.8	-1.2	-.6	-2.1	-2.6	-2.7
	5	-.1	-.3	-.6	-1.0	-.8	-1.8	-1.4	-1.8
	10	-.2	-.3	-.3	-.4				
	11	-.1	-.1	0	.1	-.1	-.1	0	.2
9	1	0	-.1	-.4	-.7	-.3	-1.7	-3.1	-2.9
	5	-.1	-.1	-.2	-.2	-.1	-1.2	-1.9	-1.6
	10	0	-.1	-.1	-.1				
	11	0	0	0	0	.1	-.1	-.1	0

TABLE A-13. BACTERIAL INACTIVATION, HOLDING TANK STUDIES, pH 6.0, 0.18 to 0.28 mg/1 INITIAL FREE CHLORINE

Run #	Temp °C	% Autoclaved Sewage	Bkpt mg/l	Chlorine Residual, mg/l						Coliform, log N/N_o				*S. typhimurium*, log N/N_o				*S. sonnei*, log N/N_o			
				0 Time		2 minutes		120 minutes		2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.
				Free	Total	Free	Total	Free	Total												
27	0	.10	150	.28	.38	.11	.30	.05	.29	<-3.3	<-3.3	<-3.3	<-3.3	<-3.5	<-3.5	<-3.5	<-3.5	<-3.0	<-3.0	<-3.0	<-3.0
		.20		.28	.38	.09	.30	.04	.27	<-3.6	<-3.6	<-3.6	<-3.6	<-3.4	-3.8	<-3.8	<-3.8	<-3.3	<-3.3	<-3.3	<-3.3
		.50		.28	.38	.08	.29	.01	.27	<-4.0	<-4.0	<-4.0	<-4.0	-4.0	<-4.2	<-4.2	<-4.2	<-3.7	<-3.7	<-3.7	<-3.7
		.10		0	0	0	0	0	0	-.1	-.1	0.1	.2	-.1	-.1	0	.2	-.1	-.1	0	.2
29	10	.10	220	.24	.34	.06	.25	.03	.21	-3.0	<-3.2	<-3.2	<-3.2	-3.0	<-3.5	<-3.5	<-3.5	<-3.2	<-3.2	<-3.2	<-3.2
		.20		.24	.34	.05	.23	.02	.22	-3.2	<-3.5	<-3.5	<-3.5	-2.9	-3.3	-3.8	<-3.8	-3.2	<-3.5	<-3.5	<-3.5
		.50		.24	.34	.03	.19	.01	.18	-3.1	-3.5	-3.3	-3.9	-2.8	-3.1	-3.3	-4.2	<-3.9	<-3.9	<-3.9	<-3.9
		.10		0	0	0	0	0	0	.1	-.3	.2	-.1	-.1	0	.1	-.1	.1	-.2	.2	-.3
31	10	.10	220	.28	.42	.08	.27	.04	.23	<-3.7	<-3.7	<-3.7	<-3.7	-3.6	<-3.6	<-3.6	<-3.6	<-3.5	<-3.5	<-3.5	<-3.5
		.20		.28	.42	.05	.25	.02	.24	-3.2	<-4.0	<-4.0	<-4.0	-2.9	-3.8	-3.8	<-4.0	-3.8	<-3.8	<-3.8	<-3.8
		.50		.28	.42	.03	.21	.01	.21	<-4.4	<-4.4	<-4.4	<-4.4	-3.6	-3.9	-4.2	<-4.3	<-4.2	<-4.2	<-4.2	<-4.2
		.10		0	0	0	0	0	0	0	0	0	0	0	0	0	.1	0	0	-.1	0
24	20	.10	150	.18	.30	.03	.22	.03	.17	-3.1	<-3.2	<-3.2	<-3.2	-2.5	<-3.4	<-3.4	<-3.4	<-3.0	<-3.0	<-3.0	<-3.0
		.50		.18	.30	.01	.20	.01	.16	-2.8	-3.6	<-3.9	<-3.9	-2.2	-2.8	-3.3	-3.8	-2.8	-3.5	<-3.7	<-3.7
		1.00		.18	.30	.01	.17	.01	.15	-.8	-2.8	-3.4	<-4.2	-1.1	-2.1	-2.5	-3.1	-.7	-2.8	<-4.0	<-4.0
		.10		0	0	0	0	0	0	.1	-.2	-.1	.1	0	-.1	0	.1	0	0	-.1	.1

TABLE A-14. VIRAL INACTIVATION, HOLDING TANK STUDIES, pH 6.0, 0.18 to 0.28 mg/1 INITIAL FREE CHLORINE

Run #	% Autoclaved Sewage	f2, log N/N_o				polio 1, log N/N_o			
		2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.
27	.10	-.9	<-2.8	<-2.8	-2.8	-.4	-2.7	<-2.7	<-2.7
	.20	-.9	-2.7	<-3.0	<-3.0	-.4	-2.3	<-2.7	<-2.7
	.50	-.9	-2.1	-2.2	-2.3				
	.10	0	0	0	0	-.1	.1	0	0
29	.10	-.8	-1.7	-1.7	-1.8	-.3	<-1.8	<-1.8	<-1.8
	.20	-.9	-1.3	-1.4	-1.4	-.3	-1.8	<-1.8	--
	.50	-.8	-.7	-.9	-.7				
	.10	0	0	0	0	-.1	0	.1	0
31	.10	-1.0	-1.8	-2.8	<-2.8	-.9	-3.0	<-3.0	<-3.0
	.20	-.9	-1.6	-1.6	-1.6	-.8	-2.2	-1.9	-2.3
	.50	-.8	-.9	-.9	-.9				
	.10	.1	-.1	0	0	.2	.2	-.4	-.4
24	.10	-.7	-1.3	-1.7	-1.8				
	.50	-.6	-.8	-.8	-.8				
	1.00	-.6	-.6	-.8	-.8				
	.10	.1	0	-.2	0				

TABLE A-15. BACTERIAL INACTIVATION, HOLDING TANK STUDIES, pH 6.0, 0.23 to 0.38 mg/1 INITIAL COMBINED CHLORINE

Run #	Temp °C	% Autoclaved Sewage	Bkpt mg/l	Chlorine Residual, mg/l						Coliform, log N/N$_o$				*S. typhimurium*, log N/N$_o$				*S. Sonnei*, log N/N$_o$			
				0 Time		2 minutes		120 minutes		2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.	2 min.	30 min.	60 min.	120 min.
				Free	Total	Free	Total	Free	Total												
27	0	.01	150	0	.38	0	.38	0	.37	0	-.2	-.9	-3.1	.1	-.2	-.8	-2.4	0	0	-.9	<-3.1
		.05		0	.38	0	.37	0	.37	-.3	-.4	-.6	-2.0	-.3	-.5	-.6	-2.7	-.2	-.4	-.6	-3.6
		.10		0	.38	0	.37	0	.37	0	0	-.8	-2.3	.1	-.2	-.5	-2.1	--	--	--	--
		.10		0	0	0	0	0	0	-.1	-.1	-.1	.2	-.1	-.1	0	.2	-.1	-.1	0	.2
29	10	.01	220	0	.34	0	.32	0	.32	0	-.5	-2.4	<-3.1	-.2	-.7	<-3.1	<-3.1	.1	-.6	<-3.0	<-3.0
		.05		0	.34	0	.30	0	.30	-.1	-.2	-1.2	<-3.8	.1	-.5	--	<-3.2	0	-1.0	--	<-3.7
		.10		0	.34	0	.30	0	.30	.1	-.3	-1.6	<-4.1	.1	-.5	--	<-4.1	0	-2.0	--	<-4.0
		.10		0	0	0	0	0	0	.1	-.3	.2	-.1	-.1	0	.1	-.1	.1	-.2	.2	-.3
5	20	.01	230	0	.23	0	.25	0	.20	.1	0	-.7	<-2.1	0	.1	-.6	<-2.3	.2	0	-1.6	<-2.2
		.05		0	.23	0	.23	0	.20	0	0	-.6	<-2.8	.2	0	-.7	<-3.0	.2	-.1	-1.5	<-2.9
		.10		0	.23	0	.21	0	.19	0	.1	-.4	-3.1	0	.1	-.2	-2.1	0	-.1	-1.2	<-3.2
		.125		0	0	0	0	0	0	.1	.1	-.1	0	-.1	.1	-.1	.1	.1	0	-.3	0
24	20	.01	150	0	.30	0	.28	0	.27	-.2	-1.0	<-3.3	<-3.3	-.5	-.7	-3.2	<-3.5	-.2	-1.9	<-3.3	<-3.3
		.05		0	.30	0	.27	0	.26	-.1	-.8	-3.4	<-4.0	-.3	-.8	-2.5	<-4.2	-.1	--	<-4.0	<-4.0
		.10		0	.30	0	.28	0	.26	-.1	-1.0	-3.8	<-4.3	-.3	-.6	-3.1	<-4.5	-.2	--	<-4.3	<-4.3
		.10		0	0	0	0	0	0	.1	-.2	-.1	.1	0	-.1	0	.1	0	0	-.1	.1
8	30	.01	270	0	.27	0	.25	0	.25	0	-1.0	<-2.3	<-2.3	.1	.1	-2.6	<-2.6	0	-1.9	<-2.2	<-2.2
		.05		0	.27	0	--	0	.23	.2	-1.3	<-3.0	<-3.0	.2	0	-2.9	<-3.3	0	-1.9	<-2.9	<-2.9
		.10		0	.27	0	.27	0	.21	0	-1.1	-2.7	<-3.3	-.1	-.1	-2.3	<-3.6	-.1	-1.8	<-3.2	<-3.2
		.125		0	0	0	0	0	0	0	0	-.1	0	0	0	0	0	-.1	0	-.1	0

TABLE A-16. VIRAL INACTIVATION, HOLDING TANK STUDIES, pH 6.0, 0.23 to 0.38 mg/1 INITIAL COMBINED CHLORINE

Run #	% Autoclaved Sewage	f2, log N/N_o 2 min.	30 min.	60 min.	120 min.	polio 1, log N/N_o 2 min.	30 min.	60 min.	120 min.
27	.01	-.2	-.3	-.1	-.1	-.1	.1	-.4	-.9
	.05	-.1	-.3	-.2	-.3	0	.2	-.4	-.6
	.10	-.3	-.1	-.2	-.1				
	.10	0	0	0	0	-.1	.1	0	0
29	.01	0	0	-.2	-.1	.9	-.3	-.7	-1.1
	.05	0	-.1	-.3	-.2	.1	-.2	-.7	<-1.8
	.10	.1	-.1	-.1	-.3				
	.10	0	0	0	0	-.1	0	.1	0
5	.01	0	-.1	-.3	-.4				
	.05	0	.1	-.3	-.4				
	.10	.1	0	-.4	-.3				
	.125	0	.1	-.1	0				
24	.01	0	-.1	-.3	-.4				
	.05	-.1	-.1	-.3	-.4				
	.10	0	-.3	-.3	-.4				
	.10	.1	0	-.2	0				
8	.01	0	-.1	-.1	-.6				
	.05	-.2	-.1	-.2	-.5				
	.10	0	.1	-.2	-.6				
	.125	-.1	.1	0	0				

APPENDIX B. EXTENDED TIME DATA

TABLE B-1. BACTERIAL DATA, EXTENDED TIME STUDIES, DECHLORINATED CONTROLS

			%		coliform, bacteria/ml					
Run Number	Temperature °C	pH	Autoclaved Sewage	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
26	0	8	.10	1.6 E5	1.6 E5	ND	6.8 E4	ND	4.7 E4	ND
28	0	8	.10	1.6 E5	1.6 E5	ND	9.4 E4	ND	ND	4.0 E4
25	20	8	.10	1.1 E5	1.1 E5	7.4 E4	ND	ND	3.0 E4	ND
5	20	8	.13	1.8 E4	1.8 E4	1.6 E4	ND	ND	ND	ND
27	0	6	.10	2.3 E5	2.3 E5	1.2 E5	ND	ND	1.1 E5	ND
24	20	6	.10	1.6 E5	1.6 E5	1.2 E5	ND	ND	ND	ND
5	20	6	.13	1.5 E4	1.5 E4	1.5 E4	ND	ND	ND	ND
20	0	8	10	7.4 E4	7.4 E4	ND	ND	5.0 E3	ND	ND
23	20	8	10	7.4 E4	7.4 E4	1.2 E6	ND	2.7 E5	ND	4.0 E5
32	30	8	10	1.4 E5	1.4 E5	1.4 E5	2.0 E5	ND	1.6 E5	ND
19	0	6	10	1.2 E5	1.2 E5	7.3 E4	ND	ND	ND	6.4 E4
22	20	6	10	9.5 E4	9.5 E4	1.3 E6	ND	ND	ND	1.4 E5
32	30	6	10	1.6 E5	1.6 E5	2.1 E5	9.0 E4	ND	5.5 E4	ND
9	30	6	11	7.0 E4	7.0 E4	4.1 E5	6.7 E5	ND	ND	ND

TABLE B-2. BACTERIAL DATA, EXTENDED TIME STUDIES, DECHLORINATED CONTROLS

Run Number	*S. typhimurium*, bacteria/ml							*S. sonnei*, bacteria/ml						
	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
26	1.6 E5	1.6 E5	ND	5.2 E4	ND	4.4 E4	ND	1.6 E5	1.6 E5	ND	4.4 E4	ND	5.2 E4	ND
28	1.3 E5	1.3 E5	ND	9.3 E4	ND	ND	1.0 E5	1.0 E5	1.0 E5	ND	7.2 E4	ND	ND	3.5 E4
25	1.4 E5	1.4 E5	4.7 E4	ND	ND	5.2 E4	ND	1.4 E5	1.4 E5	8.3 E4	ND	ND	3.7 E4	ND
5	3.5 E4	3.5 E4	1.6 E4	ND	ND	ND	ND	2.1 E4	2.1 E4	1.2 E4	ND	ND	ND	ND
27	2.4 E5	2.4 E5	1.1 E5	ND	ND	9.5 E4	ND	1.3 E5	1.3 E5	1.2 E5	ND	ND	8.0 E4	ND
24	1.6 E5	1.6 E5	1.3 E5	ND	ND	ND	ND	1.3 E5	1.3 E5	8.5 E4	ND	ND	ND	ND
5	2.4 E4	2.4 E4	3.2 E4	ND	ND	ND	ND	1.9 E4	1.9 E4	1.6 E4	ND	ND	ND	ND
20	8.0 E4	8.0 E4	5.0 E3	ND	ND	ND	ND	1.3 E5	1.3 E5	ND	ND	4.1 E4	ND	ND
23	7.8 E4	7.8 E4	1.6 E5	ND	5.0 E4	ND	3.0 E4	7.0 E4	7.0 E4	2.5 E4	ND	3.0 E4	ND	8.5 E4
32	2.1 E5	2.1 E5	2.5 E5	3.1 E5	ND	2.8 E5	ND	1.9 E5	1.9 E5	2.9 E5	2.7 E5	ND	2.2 E5	ND
19	1.4 E5	1.4 E5	8.3 E4	ND	ND	ND	7.4 E4	1.3 E5	1.3 E5	8.1 E4	ND	ND	ND	7.1 E4
22	1.4 E5	1.4 E5	8.8 E5	ND	ND	ND	7.0 E4	1.2 E5	1.2 E5	5.2 E5	ND	ND	ND	7.0 E5
32	2.1 E5	2.1 E5	1.7 E5	2.7 E5	ND	1.5 E5	ND	2.7 E5	2.7 E5	6.5 E5	6.0 E5	ND	1.2 E5	ND
9	2.3 E5	2.3 E5	2.9 E5	2.9 E5	ND	ND	ND	6.3 E4	6.3 E4	7.0 E4	2.6 E5	ND	ND	ND

TABLE B-3. BACTERIAL DATA, EXTENDED TIME STUDIES, pH 8.0, 0.69 to 1.45 INITIAL CHLORINE RESIDUAL

Run Number	Temperature °C	pH	% Autoclaved Sewage	Initial chlorine residual, mg/l Free	Total	24 hr. Total chlorine residual	Time 0	coliform, bacteria/ml 2 hr.	24 hr.	4 day	5 day	6 day	7 day
20	0	8	1	.69	.90	ND	7.3 E3	<1.0 E1	ND	ND	<1.0 E1	ND	ND
			5	.69	.90	ND	3.6 E4	3.1 E4	ND	ND	<1.0 E1	ND	ND
			10	.69	.90	ND	7.3 E4	5.9 E4	ND	ND	<1.0 E1	ND	ND
23	20	8	1	.92	1.13	.63	7.3 E3	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
			5	.92	1.13	.41	3.7 E4	3.4 E2	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
			10	.92	1.13	.23	7.3 E4	7.4 E3	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
32	30	8	1	1.25	1.45	.48	1.4 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
			5	1.25	1.45	.13	6.9 E4	1.5 E2	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
			10	1.25	1.45	.02	1.4 E5	1.5 E5	1.8 E5	9.0 E4	ND	1.3 E5	ND
20	0	8	1	0	.90	ND	7.3 E3	5.8 E2	ND	ND	<1.0 E1	ND	ND
			5	0	.90	ND	3.6 E4	1.8 E4	ND	ND	<1.0 E1	ND	ND
			10	0	.90	ND	7.3 E4	5.5 E4	ND	ND	<1.0 E1	ND	ND
23	20	8	1	0	1.13	.85	7.3 E3	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
			5	0	1.13	.59	3.7 E4	7.5 E2	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
			10	0	1.13	.34	7.4 E4	4.8 E3	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
9	30	8	1	0	.90	ND	6.3 E3	<1.0 E1	<1.0 E1	1.0 E1	ND	ND	ND
			5	0	.90	ND	3.2 E4	1.0 E1	<1.0 E1	1.0 E1	ND	ND	ND
			10	0	.90	ND	6.3 E4	6.1 E4	ND	1.7 E5	ND	ND	ND

TABLE B-4. BACTERIAL DATA, EXTENDED TIME STUDIES, pH 8.0, 0.69 to 1.45 INITIAL CHLORINE RESIDUAL

		S. typhimurium, bacteria/ml								*S. sonnei*, bacteria/ml				
Run Number	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
20	7.9 E3	<1.0 E1	ND	ND	<1.0 E1	ND	ND	1.3 E4	<1.0 E1	ND	ND	<1.0 E1	ND	ND
	3.9 E4	1.4 E4	ND	ND	<1.0 E1	ND	ND	6.4 E4	3.6 E4	ND	ND	<1.0 E1	ND	ND
	7.9 E4	4.5 E4	ND	ND	<1.0 E1	ND	ND	1.3 E5	9.7 E4	ND	ND	<1.0 E1	ND	ND
23	7.7 E3	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1	6.9 E3	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
	3.4 E4	3.5 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1	3.5 E4	1.0 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
	7.7 E4	4.3 E3	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1	6.9 E4	1.3 E3	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
32	2.1 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	1.9 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
	1.0 E5	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	9.4 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
	2.1 E5	2.9 E5	1.5 E5	1.3 E5	ND	1.5 E5	ND	1.9 E5	1.9 E5	2.6 E5	1.8 E5	ND	2.8 E5	ND
20	7.9 E3	3.6 E2	ND	ND	<1.0 E1	ND	ND	1.3 E4	4.5 E2	ND	ND	<1.0 E1	ND	ND
	3.9 E4	1.6 E4	ND	ND	<1.0 E1	ND	ND	6.4 E4	1.7 E4	ND	ND	<1.0 E1	ND	ND
	7.9 E4	4.6 E4	ND	ND	<1.0 E1	ND	ND	1.3 E5	7.8 E4	ND	ND	<1.0 E1	ND	ND
23	7.7 E3	3.5 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1	6.9 E3	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
	3.9 E4	8.5 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1	3.5 E4	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
	7.7 E4	5.0 E2	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1	6.9 E4	ND	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
9	2.1 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	ND	ND	5.7 E3	<1.0 E1	<1.0 E1	<1.0 E1	ND	ND	ND
	1.0 E5	<1.0 E1	<1.0 E1	ND	ND	ND	ND	2.8 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
	2.1 E5	1.6 E5	ND	1.4 E6	ND	ND	ND	5.7 E4	4.5 E4	ND	9.0 E4	ND	ND	ND

TABLE B-5. VIRAL DATA, EXTENDED TIME STUDIES, pH 8.0, 0.69 to 1.45 INITIAL CHLORINE RESIDUAL

	f2, PFU/ml						
Run Number	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
20	8.8 E3	2.9 E3	ND	ND	5.0 E1	ND	<1.0 E1
	4.4 E4	2.6 E4	ND	ND	5.8 E3	ND	3.7 E3
	8.8 E4	8.5 E4	ND	ND	2.7 E4	ND	3.1 E4
23	4.4 E3	1.1 E2	<1.0 E1	ND	ND	ND	<1.0 E1
	2.2 E4	2.0 E4	4.3 E2	ND	<1.0 E1	ND	<1.0 E1
	4.4 E4	3.5 E4	8.4 E3	ND	3.4 E2	ND	2.0 E2
32	2.2 E3	3.9 E2	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
	1.1 E4	4.8 E3	1.1 E2	<1.0 E1	ND	<1.0 E1	ND
	2.2 E4	2.1 E4	3.6 E3	2.2 E2	ND	4.5 E1	ND
20	8.8 E3	7.0 E3	ND	ND	1.1 E2	ND	<1.0 E1
	4.4 E4	3.7 E4	ND	ND	5.0 E3	ND	1.4 E3
	8.8 E4	7.7 E4	ND	ND	2.2 E4	ND	1.6 E4
23	4.4 E3	3.8 E3	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1
	2.4 E4	1.7 E4	4.4 E2	ND	<1.0 E1	ND	<1.0 E1
	4.4 E4	3.9 E4	5.9 E3	ND	3.0 E1	ND	1.0 E1

TABLE B-6. BACTERIAL DATA, EXTENDED TIME STUDIES, pH 8.0, 0.21 to 0.37 mg/l INITIAL CHLORINE RESIDUAL

Run Number	Temperature °C	pH	% Autoclaved Sewage	Initial chlorine residual, mg/l		24 hr. Total chlorine residual	coliform, bacteria/ml						
				Free	Total		Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
26	0	8	.1	.23	.35	ND	2.2 E4	6.9 E2	ND	<1.0 E1	ND	<1.0 E1	ND
			.2	.23	.35	ND	4.4 E4	1.4 E4	ND	<1.0 E1	ND	<1.0 E1	ND
			.5	.23	.35	ND	1.1 E5	7.0 E4	ND	<1.0 E1	ND	<1.0 E1	ND
28	0	8	.1	.21	.34	ND	2.4 E4	<1.0 E1	ND	<1.0 E1	ND	ND	<1.0 E1
			.2	.21	.34	ND	4.8 E4	<1.0 E1	ND	2.0 E1	ND	ND	1.0 E1
			.5	.21	.34	ND	1.2 E5	3.3 E4	ND	<1.0 E1	ND	ND	<1.0 E1
25	20	8	.1	.25	.37	.14	4.8 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
			.5	.25	.37	.15	2.4 E5	1.4 E3	<1.0 E1	ND	ND	<1.0 E1	ND
			1.0	.25	.37	.14	4.8 E5	2.8 E5	<1.0 E1	ND	ND	<1.0 E1	ND
26	0	8	.01	0	.35	ND	1.6 E5	1.1 E4	ND	<1.0 E1	ND	<1.0 E1	ND
			.05	0	.35	ND	8.0 E4	5.0 E4	ND	<1.0 E1	ND	<1.0 E1	ND
			.10	0	.35	ND	1.6 E5	1.0 E5	ND	<1.0 E1	ND	<1.0 E1	ND
28	0	8	.01	0	.34	ND	1.6 E4	1.4 E4	ND	<1.0 E1	ND	ND	<1.0 E1
			.05	0	.34	ND	8.0 E4	6.5 E4	ND	<1.0 E1	ND	ND	<1.0 E1
			.10	0	.34	ND	1.6 E5	1.4 E5	ND	<1.0 E1	ND	ND	<1.0 E1
5	20	8	.01	0	.23	.17	1.4 E3	1.1 E2	<1.0 E1	ND	ND	ND	ND
			.05	0	.23	.16	7.2 E3	7.5 E2	<1.0 E1	ND	ND	ND	ND
			.10	0	.23	.16	1.4 E4	1.1 E3	<1.0 E1	ND	ND	ND	ND
25	20	8	.01	0	.37	.30	2.4 E4	4.1 E2	<1.0 E1	ND	ND	<1.0 E1	ND
			.05	0	.37	.20	1.2 E5	1.7 E3	<1.0 E1	ND	ND	<1.0 E1	ND
			.10	0	.37	.23	2.4 E5	4.0 E3	<1.0 E1	ND	ND	<1.0 E1	ND

TABLE B-7. BACTERIAL DATA, EXTENDED TIME STUDIES, pH 8.0, 0.21 to 0.37 mg/1 INITIAL CHLORINE RESIDUAL

		S. typhimurium, bacteria/ml							*S. sonnei*, bacteria/ml					
Run Number	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
26	2.6 E4	4.0 E1	ND	<1.0 E1	ND	<1.0 E1	ND	1.5 E4	<1.0 E1	ND	<1.0 E1	ND	<1.0 E1	ND
	5.2 E4	1.2 E3	ND	<1.0 E1	ND	<1.0 E1	ND	3.0 E4	1.0 E2	ND	<1.0 E1	ND	<1.0 E1	ND
	1.3 E5	3.5 E3	ND	<1.0 E1	ND	<1.0 E1	ND	7.5 E4	1.0 E3	ND	<1.0 E1	ND	<1.0 E1	ND
28	2.8 E4	<1.0 E1	ND	<1.0 E1	ND	ND	<1.0 E1	1.6 E4	<1.0 E1	ND	<1.0 E1	ND	ND	<1.0 E1
	5.6 E4	<1.0 E1	ND	<1.0 E1	ND	ND	<1.0 E1	3.2 E4	<1.0 E1	ND	<1.0 E1	ND	ND	<1.0 E1
	1.4 E5	7.5 E3	ND	<1.0 E1	ND	ND	<1.0 E1	1.6 E5	9.0 E3	ND	<1.0 E1	ND	ND	<1.0 E1
25	4.0 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND	4.3 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	2.0 E5	1.1 E3	1.0 E1	ND	ND	<1.0 E1	ND	2.2 E5	ND	<1.0 E1	ND	ND	<1.0 E1	ND
	4.0 E5	8.0 E4	1.0 E1	ND	ND	<1.0 E1	ND	4.3 E5	1.0 E5	<1.0 E1	ND	ND	<1.0 E1	ND
26	1.5 E4	5.2 E3	ND	<1.0 E1	ND	<1.0 E1	ND	1.6 E4	4.9 E3	ND	<1.0 E1	ND	<1.0 E1	ND
	7.5 E4	3.2 E4	ND	<1.0 E1	ND	<1.0 E1	ND	8.0 E4	3.4 E4	ND	<1.0 E1	ND	<1.0 E1	ND
	1.5 E5	8.9 E4	ND	<1.0 E1	ND	<1.0 E1	ND	1.6 E5	1.5 E4	ND	<1.0 E1	ND	<1.0 E1	ND
28	1.3 E4	1.6 E4	ND	<1.0 E1	ND	ND	<1.0 E1	1.0 E4	1.3 E4	ND	<1.0 E1	ND	ND	<1.0 E1
	6.5 E4	5.1 E4	ND	<1.0 E1	ND	ND	<1.0 E1	5.0 E4	2.7 E4	ND	<1.0 E1	ND	ND	<1.0 E1
	1.3 E5	1.8 E5	ND	<1.0 E1	ND	ND	<1.0 E1	1.0 E5	7.0 E4	ND	<1.0 E1	ND	ND	<1.0 E1
5	2.8 E3	3.9 E2	<1.0 E1	ND	ND	ND	ND	1.7 E3	1.9 E2	<1.0 E1	ND	ND	ND	ND
	1.4 E4	2.7 E3	<1.0 E1	ND	ND	ND	ND	8.4 E3	1.1 E3	<1.0 E1	ND	ND	ND	ND
	2.8 E4	4.8 E3	<1.0 E1	ND	ND	ND	ND	1.7 E4	2.0 E3	<1.0 E1	ND	ND	ND	ND
25	2.3 E4	4.5 E1	<1.0 E1	ND	ND	<1.0 E1	ND	1.9 E4	1.5 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	1.2 E5	1.3 E3	<1.0 E1	ND	ND	<1.0 E1	ND	9.5 E4	2.5 E2	<1.0 E1	ND	ND	<1.0 E1	ND
	2.3 E5	6.0 E2	<1.0 E1	ND	ND	<1.0 E1	ND	1.9 E5	6.0 E2	<1.0 E1	ND	ND	<1.0 E1	ND

TABLE B-8. VIRAL DATA, EXTENDED TIME STUDIES, pH 8.0, 0.21 to 0.37 mg/1 INITIAL CHLORINE RESIDUAL

	f2, PFU/ml						
Run Number	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
26	6.5 E3	1.1 E3	ND	<1.0 E1	ND	<1.0 E1	ND
	1.3 E4	7.1 E3	ND	1.6 E2	ND	3.0 E1	ND
	3.3 E4	1.4 E4	ND	2.4 E2	ND	2.0 E1	ND
28	2.3 E3	<1.0 E1	ND	<1.0 E1	ND	ND	<1.0 E1
	4.6 E3	4.3 E2	ND	<1.0 E1	ND	ND	<1.0 E1
	1.2 E4	8.2 E3	ND	7.6 E2	ND	ND	1.0 E2
25	4.0 E3	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	2.0 E4	1.2 E4	3.4 E2	ND	ND	<1.0 E1	ND
	4.0 E4	3.3 E4	3.9 E3	ND	ND	<1.0 E1	ND
26	5.5 E2	4.6 E2	ND	<1.0 E1	ND	ND	ND
	2.8 E3	2.2 E3	ND	2.5 E1	ND	ND	ND
	5.5 E3	5.3 E3	ND	1.0 E2	ND	ND	ND
28	2.3 E2	2.8 E2	ND	2.5 E1	ND	ND	<1.0 E1
	1.2 E3	1.0 E3	ND	1.7 E2	ND	ND	<1.0 E1
	2.3 E3	2.8 E3	ND	4.5 E2	ND	ND	1.2 E2
25	4.0 E2	1.8 E2	<1.0 E1	ND	ND	<1.0 E1	ND
	2.0 E3	1.4 E3	<1.0 E1	ND	ND	<1.0 E1	ND
	4.0 E3	2.9 E3	<1.0 E1	ND	ND	<1.0 E1	ND

TABLE B-9. BACTERIAL DATA, EXTENDED TIME STUDIES, pH 6.0, .75 to 1.45 INITIAL CHLORINE RESIDUAL

Run Number	Temperature °C	pH	% Autoclaved Sewage	Initial chlorine residual, mg/l Free	Initial chlorine residual, mg/l Total	24 hr. Total chlorine residual	coliform, bacteria/ml Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
19	0	6	1	.75	.91	.71	1.2 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
			5	.75	.91	.45	5.9 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
			10	.75	.91	.25	1.2 E5	8.3 E3	<1.0 E1	ND	ND	ND	<1.0 E1
22	20	6	1	.92	1.15	.62	9.4 E3	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
			5	.92	1.15	.32	4.7 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
			10	.92	1.15	.11	9.4 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
32	30	6	1	1.26	1.45	.46	1.6 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
			5	1.26	1.45	.10	7.9 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
			10	1.26	1.45	0	1.6 E5	8.7 E4	9.5 E4	5.3 E4	ND	5.0 E4	ND
19	0	6	1	0	.88	1.05	1.2 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
			5	0	.88	.77	5.9 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
			10	0	.88	.44	1.2 E5	9.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
22	20	6	1	0	1.15	.89	9.4 E3	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
			5	0	1.15	.51	4.7 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
			10	0	1.15	.23	9.4 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
9	30	6	1	0	.90	ND	6.3 E3	<1.0 E1	<1.0 E1	<1.0 E1	ND	ND	ND
			5	0	.90	ND	3.2 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
			10	0	.90	ND	6.3 E4	5.8 E4	ND	6.0 E5	ND	ND	ND

TABLE B-10. BACTERIAL DATA, EXTENDED TIME STUDIES, pH 6.0, .75 to 1.45 INITIAL CHLORINE RESIDUAL

	S. typhimurium, bacteria/ml							*S. sonnei*, bacteria/ml						
Run Number	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
19	1.4 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1	1.3 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
	6.9 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1	6.4 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
	1.4 E5	8.3 E3	<1.0 E1	ND	ND	ND	<1.0 E1	1.3 E5	7.0 E3	<1.0 E1	ND	ND	ND	<1.0 E1
22	1.4 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1	1.2 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
	6.9 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1	5.9 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
	1.4 E5	3.5 E1	<1.0 E1	ND	ND	ND	<1.0 E1	1.2 E5	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
32	2.1 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	2.7 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
	1.0 E5	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND	1.3 E5	<1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
	2.1 E5	1.1 E5	1.1 E5	1.9 E5	ND	4.5 E4	ND	2.7 E5	1.4 E5	3.4 E5	2.8 E5	ND	4.7 E4	ND
19	1.4 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1	1.3 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
	6.9 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1	6.4 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	<1.0 E1
	1.4 E5	1.3 E2	<1.0 E1	ND	ND	ND	<1.0 E1	1.3 E5	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
22	1.4 E4	<1.0 E1	ND	ND	ND	ND	<1.0 E1	1.2 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
	6.9 E4	<1.0 E1	ND	ND	ND	ND	<1.0 E1	5.9 E4	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
	1.4 E5	<1.0 E1	ND	ND	ND	ND	<1.0 E1	1.2 E5	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
9	2.1 E4	<1.0 E1	<1.0 E1	<1.0 E1	ND	ND	ND	5.7 E3	<1.0 E1	<1.0 E1	<1.0 E1	ND	ND	ND
	1.0 E5	<1.0 E1	<1.0 E1	ND	ND	ND	ND	2.8 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
	2.1 E5	1.4 E5	ND	9.1 E5	ND	ND	ND	5.7 E4	5.5 E4	ND	6.0 E4	ND	ND	ND

TABLE B-11. VIRAL DATA, EXTENDED TIME STUDIES, pH 6.0, .75 to 1.45 INITIAL CHLORINE RESIDUAL

		f2, PFU/ml					
Run Number	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
19	7.0 E3	6.0 E1	ND	ND	ND	ND	<1.0 E1
	3.5 E4	6.7 E3	ND	ND	ND	ND	7.3 E2
	7.0 E4	3.4 E4	ND	ND	ND	ND	1.2 E4
22	8.4 E3	<1.0 E1	<1.0 E1	ND	ND	ND	<1.0 E1
	4.2 E4	4.8 E3	1.4 E2	ND	ND	ND	<1.0 E1
	8.4 E4	4.1 E4	7.2 E3	ND	ND	ND	3.9 E3
32	4.2 E3	1.0 E1	<1.0 E1	<1.0 E1	ND	<1.0 E1	ND
	2.1 E4	1.6 E3	1.0 E1	<1.0 E1	ND	<1.0 E1	ND
	4.2 E4	2.3 E4	1.9 E4	1.7 E4	ND	3.3 E3	ND
19	7.0 E3	5.4 E3	ND	ND	ND	ND	<1.0 E1
	3.5 E4	2.4 E4	ND	ND	ND	ND	1.3 E3
	7.0 E4	5.8 E4	ND	ND	ND	ND	6.9 E3
22	8.4 E3	2.8 E3	8.0 E1	ND	ND	ND	<1.0 E1
	4.2 E4	1.4 E4	5.8 E2	ND	ND	ND	<1.0 E1
	8.4 E4	3.5 E4	2.2 E3	ND	ND	ND	2.1 E2

TABLE B-12. BACTERIAL DATA, EXTENDED TIME STUDIES, pH 6.0, 0.18 to 0.38 INITIAL CHLORINE RESIDUAL

Run Number	Temperature °C	pH	% Autoclaved Sewage	Initial chlorine residual, mg/l Free	Initial chlorine residual, mg/l Total	24 hr. Total chlorine residual	Time 0	coliform, bacteria/ml 2 hr.	24 hr.	4 day	5 day	6 day	7 day
27	0	6	.1	.28	.38	.23	2.1 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
			.2	.28	.38	.23	4.2 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
			.5	.28	.38	.23	1.1 E5	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
24	20	6	.1	.18	.30	.22	1.7 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
			.5	.18	.30	.18	8.5 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
			1.0	.18	.30	.15	1.7 E5	<1.0 E1	<1.0 E1	ND	ND	ND	ND
27	0	6	.01	0	.38	.37	2.3 E4	2.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
			.05	0	.38	.35	1.2 E5	1.1 E3	<1.0 E1	ND	ND	<1.0 E1	ND
			.10	0	.38	.34	2.3 E5	1.1 E3	<1.0 E1	ND	ND	<1.0 E1	ND
5	20	6	.01	0	.23	ND	1.2 E3	<1.0 E1	<1.0 E1	ND	ND	ND	ND
			.05	0	.23	.12	6.0 E3	<1.0 E1	<1.0 E1	ND	ND	ND	ND
			.10	0	.23	.11	1.2 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
24	20	6	.01	0	.30	.33	2.1 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
			.05	0	.30	.32	1.1 E5	<1.0 E1	<1.0 E1	ND	ND	ND	ND
			.10	0	.30	.32	2.1 E5	<1.0 E1	<1.0 E1	ND	ND	ND	ND

TABLE B-13. BACTERIAL DATA, EXTENDED TIME STUDIES, pH 6.0, 0.18 to 0.38 INITIAL CHLORINE RESIDUAL

Run Number	*S. typhimurium*, bacteria/ml							*S. sonnei*, bacteria/ml						
	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
27	3.1 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND	1.1 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	6.2 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND	2.2 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	1.6 E5	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND	5.5 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
24	2.6 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND	9.0 E3	<1.0 E1	<1.0 E1	ND	ND	ND	ND
	1.3 E5	2.0 E1	<1.0 E1	ND	ND	ND	ND	4.5 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
	2.6 E5	1.9 E2	<1.0 E1	ND	ND	ND	ND	9.0 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
27	2.4 E4	9.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND	1.3 E4	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	1.2 E5	2.2 E2	<1.0 E1	ND	ND	<1.0 E1	ND	6.5 E4	1.5 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	2.4 E5	2.0 E3	<1.0 E1	ND	ND	<1.0 E1	ND	1.3 E5	ND	<1.0 E1	ND	ND	<1.0 E1	ND
5	1.9 E3	<1.0 E1	<1.0 E1	ND	ND	ND	ND	1.5 E3	<1.0 E1	<1.0 E1	ND	ND	ND	ND
	9.6 E3	<1.0 E1	<1.0 E1	ND	ND	ND	ND	7.6 E3	<1.0 E1	<1.0 E1	ND	ND	ND	ND
	1.9 E4	1.7 E2	<1.0 E1	ND	ND	ND	ND	1.5 E4	1.0 E3	<1.0 E1	ND	ND	ND	ND
24	3.0 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND	1.8 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
	1.5 E5	<1.0 E1	<1.0 E1	ND	ND	ND	ND	9.0 E4	<1.0 E1	<1.0 E1	ND	ND	ND	ND
	3.0 E5	<1.0 E1	<1.0 E1	ND	ND	ND	ND	1.8 E5	<1.0 E1	<1.0 E1	ND	ND	ND	ND

TABLE B-14. VIRAL DATA, EXTENDED TIME STUDIES, pH 6.0, 0.18 to 0.38 INITIAL CHLORINE RESIDUAL

	f2, PFU/ml						
Run Number	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
27	5.6 E3	<1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	1.1 E4	1.0 E1	<1.0 E1	ND	ND	<1.0 E1	ND
	2.8 E4	1.5 E2	1.5 E1	ND	ND	<1.0 E1	ND
24	6.2 E3	1.0 E2	<1.0 E1	ND	ND	ND	ND
	3.1 E4	4.8 E3	5.8 E2	ND	ND	ND	ND
	6.2 E4	1.1 E4	2.6 E3	ND	ND	ND	ND
27	5.6 E2	4.7 E2	7.0 E1	ND	ND	1.0 E1	ND
	2.8 E3	1.3 E3	3.7 E2	ND	ND	5.5 E1	ND
	5.6 E3	5.0 E3	5.7 E2	ND	ND	8.5 E1	ND
24	6.2 E2	2.7 E2	2.0 E1	ND	ND	ND	ND
	3.1 E3	1.3 E3	<1.0 E1	ND	ND	ND	ND
	6.2 E3	2.6 E3	1.9 E2	ND	ND	ND	ND

TABLE B-15. VIRAL DATA, EXTENDED TIME STUDIES, DECHLORINATED CONTROLS

	f2, PFU/ml						
Run Number	Time 0	2 hr.	24 hr.	4 day	5 day	6 day	7 day
26	5.5 E3	5.5 E3	ND	3.0 E3	ND	2,4 E3	ND
28	2.3 E3	2.3 E3	ND	3.6 E3	ND	ND	2.0 E3
25	4.0 E3	4.0 E3	3.3 E3	ND	ND	3.9 E2	ND
27	5.6 E3	5.6 E3	5.3 E3	ND	ND	4.2 E3	ND
24	6.2 E3	6.2 E3	5.2 E3	ND	ND	ND	ND
20	8.5 E4	8.5 E4	ND	ND	4.1 E3	ND	ND
23	4.4 E4	4.4 E4	3.7 E5	ND	1.9 E4	ND	1.9 E4
32	2.2 E4	2.2 E4	7.2 E3	3.2 E4	ND	1.8 E2	ND
22	8.5 E4	8.5 E4	5.0 E4	ND	ND	ND	7.1 E4
32	4.2 E4	4.2 E4	3.3 E4	3.4 E4	ND	2.3 E4	ND

APPENDIX C. RESERVOIR DATA

TABLE C-1. BACTERIAL AND VIRAL INACTIVATION, RESERVOIR STUDIES

Water Source	% Sewage Added	Time, Minutes	pH	Free Cl, mg/1	Total Cl mg/1	f2 log N/No	Coliform log N/No	Turbidity NTU	Run #
tap	2	0	8.4	1.5	2.1			.38	5
		10	8.6	.02	1.7	-1.5	- .8	1.2	
		30	8.4	.02	1.7	< -3.7	-1.7	1.0	
		60	8.5	.2	1.6	< -3.7	-2.4	.7	
		90	8.5	.4	1.4	< -3.7	-2.4	.7	
		120	8.6	.5	1.3	< -3.7	-1.5	.7	
tap	2	0	8.5	.8	2.0			.58	5
		10	8.5	.01	1.7	-1.5	- .8	1.1	
		30	8.5	.04	1.7	< -3.7	- .7	1.0	
		60	8.5	.2	1.6	< -3.7	-2.6	.9	
		90	8.5	.4	1.4	< -3.7	-2.6	.8	
		120	8.5	.5	1.3	< -3.7	-2.0	.7	
tap: river 1:1 mixture	2	0	7.2	1.6	2.2			4.0	5
		10	7.3	.06	2.0	-1.3	-1.5	4.3	
		30	7.4	.06	1.7	< -3.7	-1.8	3.9	
		60	7.5	.1	1.1	< -3.7	-2.3	4.0	
		90	7.5	.2	.9	< -3.7	-2.6	3.7	
		120	7.6	.3	.9	< -3.7	-3.2	3.8	
tap: river 1:1 mixture	2	0	8.3	1.6	2.1			-	5
		10	7.1	.07	1.9	-1.0	- .1	4.6	
		30	7.1	.1	1.7	< -3.7	-1.5	3.9	
		60	7.2	.2	1.2	< -3.7	-2.6	3.5	
		90	7.3	.2	1.0	< -3.7	-2.8	4.0	
		120	7.3	.4	.9	< -3.7	-2.5	4.0	
river	2	0	6.7	1.6	2.7			7.3	5
		10	6.9	.2	2.1	-1.9	-1.7	5.9	
		30	6.8	.2	2.0	< -3.7	-1.8	6.0	
		60	6.9	.3	1.6	< -3.7	-2.6	6.0	
		90	6.9	.4	1.1	< -3.7	< -3.4	5.9	
		120	7.1	.5	1.0	< -3.7	-2.6	6.5	
								5.9	5
river	2	0	6.7	1.7	2.6	-2.1	- .5	6.3	
		10	6.7	.2	2.1	-3.5	-2.4	5.8	
		30	6.7	.3	2.1	< -3.7	-3.1	5.9	
		60	6.8	.3	1.9	< -3.7	< -3.4	6.8	
		90	6.9	.4	1.1	< -3.7	< -3.4	6.6	
		120	6.9	.5	.9				

TABLE C-2. BACTERIAL AND VIRAL INACTIVATION, RESERVOIR STUDIES

Water Source	% Sewage Added	Time, Minutes	pH	Free Cl, mg/l	Total Cl mg/l	f2 log N/No	Coliform log N/No	Turbidity NTU	Run #
tap	1	0	8.2	.41	.85				2
		10	8.4	0	.62	- .7	- .2	2.5	
		30	8.4	0	.67	- .8	-1.2	1.5	
		60	8.4	0	.67	-1.4	-1.9	1.5	
		90	8.4	0	.72	-2.2	-2.7	1.5	
		120	8.3	0	.70	< -5.1	-3.2	1.2	
tap	5	0	8.2	.38	.79			3.3	2
		10	8.1	0	.35	- .6	- .3	3.4	
		30	8.2	0	.37	- .8	- .6	2.9	
		60	8.2	0	.48	- .9	-1.5	2.4	
		90	8.1	0	.74	-1.3	-1.6	2.0	
		120	8.2		.62	-1.3	-1.8		
tap	10	0	8.2	.52	.93	- .6	- .2	5.3	2
		10	8.1	0	.14	- .6	- .8	5.1	
		30	8.0	0	.21	- .8	- .8	4.2	
		60	8.1	0	.39	-1.0	-2.0	3.1	
		90	8.1	0	.49	-1.1	-2.0	2.8	
		120	8.1	0	.55				
tap	1	0	8.2	0	1.5				2
		10	8.3		1.3	- .6	- .9	2.0	
		30	8.4		1.4	-1.0	-2.0	2.0	
		60	8.4		1.4	-1.4	-3.4	1.3	
		90	8.3		1.4	-1.7	-4.0	1.1	
		120	8.3		1.4	-3.0	-4.0	1.1	
tap	5	0	8.3	0	1.5				2
		10	8.2		1.0	- .7	- .6	3.4	
		30	8.2		1.1	- .8	-1.6	3.1	
		60	8.2		1.1	-1.1	-2.3	2.3	
		90	8.2		1.3	-1.3	-3.4	1.9	
		120	8.2		1.3	-1.5	-3.5	1.7	
tap	10	0	8.3	0	1.5				2
		10	8.2		.7	- .5	- .6	5.2	
		30	8.2		.7	- .7	-1.7	4.8	
		60	8.2		.7	-1.1	-2.4	3.5	
		90	8.2		.9	-1.5	-2.5	3.0	
		120	8.2		1.0	-1.4	-3.1	2.5	

TABLE C-3. BACTERIAL AND VIRAL INACTIVATION, RESERVOIR STUDIES

Water Source	% Sewage Added	Time, Minutes	pH	Free Cl, mg/l	Total Cl mg/l	f2 log N/No	Coliform log N/No	Turbidity NTU	Run #
tap	1	0	8.1	0	2.0			.8	4
		10	8.2		1.8	- .5	.5	2.0	
		30	8.1		1.9	- .3	- .3	1.5	
		60	8.2		1.8	-2.4	-2.4	1.2	
		90	7.9		1.9	-2.9	-2.9	1.1	
		120	8.1		1.8	-2.7	-2.7	1.0	
tap	1	0	8.1	0	2.0			1.0	6
		10	7.6		1.9	- .7	1.0	2.0	
		30	8.1		1.9	- .3	-1.1	1.6	
		60	8.0		1.9	- .9	-2.1	1.3	
		90	8.0		1.9	- .8	-1.6	1.2	
		120	8.0		1.9	-1.3	-2.2	1.1	
tap: river 1:1 mixture	1	0	7.5	0	1.6			115	4
		10	7.5		1.4	0	.7	120	
		30	7.4		1.4	0	-1.3	100	
		60	7.5		1.3	- .2	-1.8	110	
		90	7.4		1.3	- .3	-2.5	110	
		120	7.5		1.4	- .3	< -2.7	110	
tap: river 1:1 mixture	1	0	7.3	0	1.5			145	6
		10	7.3		1.4	- .3	.5	120	
		30	7.3		1.4	- .2	-1.3	105	
		60	7.2		1.4	- .3	-2.6	110	
		90	7.3		1.3	- .3	-2.1	110	
		120	7.3		1.4	- .3	-2.2	110	
river	1	0	7.2	0	1.3			200	4
		10	7.2		1.1	- .1	.4	210	
		30	7.3		1.1	0	-1.4	200	
		60	7.2		.9	- .1	-2.1	200	
		90	7.1		1.0	- .2	-2.5	200	
		120	7.1		.9	- .2	- .9	200	
river	1	0	7.0	0	1.3			200	6
		10	7.0		1.1	- .1	0	200	
		30	7.0		1.1	- .1	-1.3	190	
		60	7.0		1.0	- .2	-2.4	195	
		90	7.1		.9	- .3	-1.8	200	
		120	6.9		.9	- .3	-1.5	190	

TABLE C-4. BACTERIAL AND VIRAL INACTIVATION, RESERVOIR STUDIES

Water Source	% Sewage Added	Time, Minutes	pH	Free Cl, mg/l	Total Cl mg/l	f2 log N/No	Coliform log N/No	Turbidity NTU	Run #
tap	1	0	8.0	0	1.3			.8	8
		10	8.1		1.2	-.6	0	1.1	
		30	8.1		1.2	-1.2	- .8	1.6	
		60	8.1		1.2	-1.4	-3.3	2.0	
		90	8.1		1.2	-2.3	-3.3	.7	
		120	8.1		1.2	-3.1	-3.8	.7	
tap	1	0	-	0	-			.8	8
		10	8.1		1.2	- .8	0	1.1	
		30	8.1		1.2	-1.1	-1.4	1.0	
		60	8.1		1.2	-1.4	-1.6	1.1	
		90	8.1		1.2	-1.9	-3.5	.8	
		120	8.1		1.2	-2.5	-4.1	.8	
tap: river 1:1 mixture	1	0	7.9	0	1.2			4.8	8
		10	8.0		1.1	- .5	0	3.2	
		30	7.8		1.1	- .8	- .5	4.3	
		60	8.0		1.1	- .9	-1.4	4.4	
		90	7.9		1.1	-1.0	-2.5	4.1	
		120	8.0		1.1	- .9	-3.5	4.1	
tap: river 1:1 mixture	1	0	-	0	-			4.5	8
		10	8.0		1.1	- .6	0	3.9	
		30	8.1		1.1	- .7	- .9	4.6	
		60	8.0		1.1	- .6	-2.2	3.0	
		90	8.1		1.1	- .9	-2.8	4.0	
		120	8.0		1.1	- .9	-3.4	3.9	
river	1	0	7.8	0	1.2			8.5	8
		10	8.0		1.0	- .4	- .2	5.0	
		30	8.0		1.0	- .7	- .7	6.9	
		60	8.0		1.1	- .6	-1.8	7.6	
		90	7.9		1.0	- .8	-2.5	6.8	
		120	8.0		1.0	- .8	-2.8	6.6	
river	1	0	-	0	-			7.5	8
		10	8.0		1.0	- .3	0	5.8	
		30	8.0		1.0	- .6	- .5	6.1	
		60	7.9		1.0	- .5	-1.7	7.9	
		90	8.0		1.0	- .7	-2.3	7.2	
		120	8.0		1.0	- .7	-3.5	7.9	

APPENDIX D. MUNICIPAL DISTRIBUTION SYSTEM DATA

TABLE D-1. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 1 - FREDERICK

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Total Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/25/77	7.8	--	8.0	--	--	2900	--	4600	≥2400
8/1	7.6	--	3.5	.20	--	36	50	1800	<2.0
8/8	7.3	--	5.2	.30	.60	180	190	1300	<2.0
8/15	7.7	--	8.0	.10	.90	--	1800	2900	<2.0
8/22	8.6	--	8.8	.40	3.0	--	440	740	<2.0
8/29	7.4	--	1.9	.15	.70	75	120	98	<2.0
9/5	8.2	26.0	13.0	.50	1.8	--	1800	3400	<2.0
9/12	7.6	--	3.3	--	--	80	320	1900	<2.0
9/19	7.8	24.5	1.8	.20	1.40	85	120	380	<2.0
9/26	8.6	23.0	8.5	1.0	2.4	130	160	1200	<2.0
10/3	7.8	22.0	12.0	.90	1.0	--	560	1200	<2.0
10/10	7.7	19.0	1.0	.20	1.0	6000	8500	8400	<2.0
10/17	9.0	18.0	2.0	.30	2.4	93	100	61	<2.0
10/24	7.3	16.0	1.1	.55	.80	<1.0	2.0	31	<2.0
10/31	8.6	15.5	11.0	.30	3.0	31	39	65	<2.0
11/7	9.0	15.5	1.7	.15	1.5	15	16	160	<2.0
11/14	9.4	12.0	11.0	.35	3.0	24	35	50	<2.0
11/28	8.9	9.0	.84	.15	1.6	<1.0	3.5	11	<2.0
12/5	9.5	9.0	1.4	.20	2.0	5.5	6.0	11	<2.0
12/12	9.3	5.5	.95	.30	1.6	11	15	12	2.0
12/19	8.7	7.5	3.4	.25	3.0	7.0	11	21	<2.0
1/2/78	9.3	6.0	.68	.35	3.0	1.5	4.0	4.5	<2.0
1/9	9.4	4.0	1.1	.30	2.0	2.0	6.5	13	<2.0
1/23	9.4	4.0	.93	.20	2.0	5.5	5.5	20	<2.0
1/30	9.4	4.5	1.1	.30	3.0	5.0	11	8.0	<2.0
2/13	9.3	4.5	1.5	.30	3.0	2.5	4.5	6.5	<2.0
2/20	9.2	3.5	.75	.30	2.0	7.0	13	9.0	49
2/27	9.2	4.0	.91	.40	3.0	4.5	8.5	6.0	<2.0
3/6	9.2	3.5	5.0	.20	2.4	40	59	230	170
3/13	9.0	5.5	2.4	.15	2.0	7.5	7.5	10	<2.0
3/20	9.1	6.0	.89	.30	2.0	8.5	14	8.0	<2.0
3/27	8.4	8.0	2.9	.25	2.8	51	71	290	<2.0
4/3	8.1	9.0	1.5	.15	2.0	4.0	7.5	7.0	<2.0
4/10	8.4	11.0	1.1	.15	3.0	4.0	4.5	13	<2.0
mean			3.8	.31	2.1		441	852	
std. dev.			3.8	.20	.80		1510	1734	

TABLE D-2. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 2 - FREDERICK

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Total Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/25/77	8.4	--	2.6	--	--	230	240	79	<2.0
8/1	8.6	--	2.4	.30	--	1.0	1.0	1.5	<2.0
8/8	8.2	--	1.5	.35	3.0	9.0	11	23	<2.0
8/15	9.1	--	1.4	3.0	3.6	--	3.0	1.5	<2.0
8/22	9.3	--	2.0	.60	1.5	--	4.0	20	<2.0
8/29	9.0	--	1.3	.30	3.6	3.5	6.0	2.5	<2.0
9/5	9.7	24.5	1.0	.30	3.2	38	47	62	<2.0
9/12	9.1	--	1.3	--	--	3.5	4.5	6.5	<2.0
9/19	9.4	23.5	1.5	.50	2.2	3.5	4.5	3.5	<2.0
9/26	9.4	22.0	1.1	.25	2.8	3.5	4.0	6.0	<2.0
10/3	9.5	20.0	1.0	.35	2.4	--	4.0	3.0	<2.0
10/10	9.7	20.0	1.6	.20	3.6	4.5	4.5	1.0	<2.0
10/17	9.6	15.0	1.6	.30	2.4	10	10	6.0	<2.0
10/24	9.5	17.0	1.4	.30	3.2	1.0	3.0	2.0	<2.0
10/31	7.8	14.5	.88	3.0	4.0	1.0	1.0	3.5	<2.0
11/7	7.8	17.0	.47	.30	.55	4.0	4.5	6.5	<2.0
11/14	9.5	12.0	1.3	.30	3.0	1.0	10	5.5	<2.0
11/28	9.1	9.0	.65	.15	2.0	3.5	5.0	6.5	<2.0
12/5	9.4	8.5	.96	.30	3.0	8.0	10	5.0	<2.0
12/12	8.7	5.0	.61	.50	2.0	6.5	7.5	6.0	<2.0
12/19	8.9	8.0	1.0	.35	4.0	4.0	8.0	9.5	<2.0
1/2/78	9.3	5.5	.79	.50	3.0	3.0	--	7.0	<2.0
1/9	9.4	4.5	1.4	.50	3.0	7.5	8.0	15	<2.0
1/23	9.5	4.0	.72	.30	2.8	1.5	1.5	7.0	<2.0
1/30	9.5	4.5	.92	.55	3.0	5.5	12	11	<2.0
2/13	9.4	4.5	1.5	.35	3.0	4.0	5.0	3.5	<2.0
2/20	9.4	3.5	.78	.10	2.0	1.0	1.0	4.0	<2.0
2/27	9.2	4.0	.68	.55	2.8	1.0	2.5	6.0	<2.0
3/6	9.3	3.0	.84	.30	3.0	2.0	3.0	8.0	<2.0
3/13	7.5	5.5	1.2	.15	2.0	2.5	8.5	7.0	<2.0
3/20	9.1	6.5	.91	.50	3.0	4.5	5.0	7.5	<2.0
3/27	8.3	8.0	1.1	.35	2.2	4.5	5.5	16	<2.0
4/3	8.4	8.0	1.2	.20	2.2	7.0	8.0	13	<2.0
4/10	9.1	12.0	.94	.55	2.2	6.5	10	10	<2.0
mean			1.2	.52	2.7		14	11	
std. dev.			.48	.66	.74		41	16	

TABLE D-3. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 3 - FREDERICK

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Total Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/25/77	8.7	--	2.0	--	--	3.5	11	23	<2.0
8/1	7.9	--	3.5	.30	--	1.5	2.0	14	<2.0
8/8	7.6	--	2.0	.30	2.5	3.5	18	28	<2.0
8/15	9.2	--	4.8	.40	2.6	--	20	1.0	<2.0
8/22	9.2	--	2.5	.20	1.2	--	190	77	<2.0
8/29	8.9	--	2.4	.30	3.6	10	19	45	<2.0
9/5	9.4	28.0	3.5	.35	3.2	2.5	39	18	<2.0
9/12	9.1	--	2.6	--	--	2.5	11	10	<2.0
9/19	9.3	25.0	3.3	.40	2.4	1.0	41	30	<2.0
9/26	9.3	22.0	1.5	.30	2.2	2.0	14	17	<2.0
10/3	9.4	20.0	2.5	.30	2.2	--	16	36	<2.0
10/10	9.7	18.0	1.7	.25	4.0	4.5	5.5	6.0	<2.0
10/17	9.6	15.5	1.4	.30	2.8	7.0	8.5	7.5	<2.0
10/24	9.5	16.5	2.6	.20	3.6	2.5	7.5	11	<2.0
10/31	7.9	15.0	.85	2.0	3.0	1.0	1.0	1.0	<2.0
11/7	7.9	17.5	.72	.35	.55	2.0	3.0	3.5	<2.0
11/14	9.4	12.5	1.4	.25	2.2	4.5	10	9.5	<2.0
11/28	9.0	9.5	.59	.15	2.6	1.0	3.0	8.0	<2.0
12/5	9.4	9.0	1.1	.35	2.2	3.5	8.0	11	<2.0
12/12	9.2	6.5	.71	.50	2.0	10	5.0	9.0	<2.0
12/19	8.8	7.5	1.3	.25	2.4	5.0	15	8.0	<2.0
1/2/78	9.3	6.0	.68	.55	2.2	8.0	9.5	3.5	<2.0
1/9	9.3	6.0	1.1	.30	2.8	7.5	12	1.0	<2.0
1/23	8.8	5.0	.69	.20	2.8	3.5	4.5	4.5	<2.0
1/30	9.4	5.0	1.0	.55	3.2	7.5	7.0	75	<2.0
2/13	9.3	4.5	1.2	.25	2.8	1.0	1.5	4.0	<2.0
2/20	9.1	4.0	.84	.50	3.2	3.5	3.0	5.0	<2.0
2/27	9.1	5.0	.67	.55	2.8	4.5	5.5	6.5	<2.0
3/6	9.0	4.0	.78	.10	2.8	2.5	4.0	4.0	<2.0
3/13	8.0	6.0	1.3	.70	1.0	7.5	7.5	1.5	<2.0
3/20	9.1	7.5	1.2	.40	2.6	6.5	9.0	8.0	<2.0
3/27	8.3	8.5	1.1	.25	2.2	2.0	5.0	12	<2.0
4/3	8.1	10.5	.99	.15	2.0	4.5	4.5	4.0	<2.0
4/10	9.2	15.0	1.1	.55	2.4	4.0	6.0	5.5	<2.0
mean			1.6	.39	2.5		15	15	
std. dev.			1.0	.33	.72		32	18	

TABLE D-4. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 4 - FREDERICK

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Total Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/25/77	8.5	--	2.0	--	--	180	280	310	<2.0
8/1	8.6	--	3.0	.40	--	160	380	310	<2.0
8/8	8.3	--	1.7	.20	2.0	190	370	350	<2.0
8/15	8.9	--	1.6	.40	1.4	--	240	170	<2.0
8/22	9.2	--	1.5	.20	2.4	--	60	71	<2.0
8/29	8.4	--	1.8	.20	2.4	--	170	160	<2.0
9/5	9.6	26.0	1.4	.30	2.4	28	120	86	<2.0
9/12	8.7	--	1.4	--	--	10	280	320	<2.0
9/19	8.7	25.0	1.0	.05	1.1	12	190	280	<2.0
9/26	9.0	24.0	1.2	.15	1.4	--	430	1000	<2.0
10/3	9.5	22.5	1.4	.25	2.2	--	73	78	<2.0
10/10	9.6	19.5	1.3	.70	3.0	35	310	210	<2.0
10/17	9.3	17.0	1.5	.80	1.4	1.0	150	510	<2.0
10/24	9.5	17.0	1.2	.40	2.4	45	100	79	<2.0
10/31	9.1	17.0	1.5	.30	3.0	110	180	190	<2.0
11/7	9.0	17.0	1.3	.20	1.5	210	820	1300	<2.0
11/14	9.5	15.0	1.3	.20	1.6	260	980	970	<2.0
11/28	8.5	11.0	.71	.15	1.8	110	290	280	<2.0
12/5	9.3	10.5	1.1	.15	2.4	38	130	150	<2.0
12/12	9.3	8.0	1.1	.20	1.8	53	130	140	<2.0
12/19	7.9	8.0	1.5	.15	1.2	32	320	260	<2.0
1/2/78	9.3	6.5	1.4	.20	2.4	18	170	170	<2.0
1/9	9.3	7.0	2.5	.20	2.0	8.5	160	250	<2.0
1/23	9.3	5.5	1.3	.20	2.0	3.0	120	83	<2.0
1/30	9.4	5.5	1.1	.25	3.0	5.5	100	86	<2.0
2/13	9.1	5.0	2.1	.25	2.4	3.0	22	9.5	<2.0
2/20	9.0	5.5	1.0	.20	1.8	6.5	380	370	<2.0
2/27	8.4	5.0	1.1	.25	3.0	16	130	120	<2.0
3/6	9.0	4.0	.86	.10	2.0	2.0	33	20	<2.0
3/13	8.1	5.5	4.6	.10	2.4	7.5	16	13	<2.0
3/20	9.0	6.0	1.5	.15	1.8	4.0	32	25	<2.0
3/27	8.2	9.0	2.4	.05	2.0	4.5	62	120	<2.0
4/3	8.1	10.0	1.6	.15	2.0	8.0	190	190	<2.0
4/10	7.9	12.0	2.1	0	1.4	1.5	40	36	<2.0
mean			1.6	.23	2.1		219	256	
std. dev.			.72	.16	.54		208	292	

TABLE D-5. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 23 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.6	17.2	.40	.80	<1.0	1.0	<1.0	<2.0
7/25	7.6	17.8	.46	.80	<1.0	<1.0	--	<2.0
8/1	7.5	17.8	.81	1.0	<1.0	<1.0	<1.0	<2.0
8/8	CLOSED							
8/15	7.5	17.8	1.1	.80	--	3.0	<1.0	<2.0
8/22	7.2	17.8	.35	.90	--	1.0	1.0	<2.0
8/29	7.6	17.8	.33	1.0	1.0	1.0	<1.0	<2.0
9/5	7.2	17.8	.40	1.0	<1.0	1.0	<1.0	<2.0
9/12	7.4	17.8	.48	1.0	1.0	1.0	<1.0	<2.0
9/19	CLOSED							
9/26	7.2	17.8	.38	.80	<1.0	1.0	1.0	<2.0
10/3	7.4	16.1	.36	.80	--	<1.0	<1.0	<2.0
10/10	7.3	15.6	.41	.90	<1.0	2.5	<1.0	<2.0
10/17	7.4	13.3	.44	.80	1.0	1.0	<1.0	<2.0
10/24	7.2	12.2	.45	.80	<1.0	1.5	1.0	<2.0
10/31	7.3	11.1	.39	.80	<1.0	1.0	1.0	<2.0
11/7	7.3	13.9	.90	.90	5.0	8.5	7.0	<2.0
11/14	7.4	13.3	.77	.80	4.0	6.5	30	<2.0
11/28	7.8	9.4	.40	.80	<1.0	<1.0	1.0	<2.0
12/5	7.4	8.9	.55	1.0	6.5	8.5	9.5	<2.0
12/12	7.6	6.7	.40	.80	<1.0	<1.0	<1.0	<2.0
12/19	7.6	6.7	.41	.90	1.0	1.0	1.0	<2.0
1/2/78	7.2	5.6	.56	1.05	1.0	1.0	1.0	<2.0
1/9	7.5	4.4	.85	.80	1.0	1.0	2.0	<2.0
1/23	7.2	3.3	.65	.80	2.0	2.5	1.0	<2.0
1/30	CLOSED							
2/13	7.8	3.3	.94	.80	3.0	6.5	2.0	<2.0
2/20	7.2	2.8	.55	1.0	1.0	1.0	<1.0	<2.0
2/27	7.3	3.3	.56	.80	1.0	1.0	<1.0	<2.0
3/6	7.2	2.2	.59	.80	1.0	1.0	1.0	<2.0
3/13	7.2	3.9	.94	.80	2.0	5.0	5.0	<2.0
3/20	7.2	4.4	.80	.80	4.0	5.5	5.0	<2.0
3/27	7.2	5.6	.90	.80	1.0	1.5	1.0	<2.0
4/3	7.2	6.7	.99	.80	2.0	3.5	2.0	<2.0
4/10	7.4	8.3	1.0	.80	--	--	--	<2.0
4/17	7.4	10.0	.76	.80	1.0	3.5	8.0	<2.0
4/24	7.0	9.4	.48	.80	--	2.0	2.5	<2.0
5/1	7.4	10.0	.40	.90	--	13	13	<2.0
5/8	7.4	10.6	.52	.80	--	3.5	5.0	<2.0
5/22	7.4	13.3	.38	.80	--	1.0	2.5	<2.0
5/29	7.6	14.4	.31	.80	--	2.5	4.0	<2.0
mean			.59	.85		2.6	3.0	
std. dev.			.23	.08		2.9	5.5	

TABLE D-6. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 27 - BALTIMORE

Week of	pH	Temp °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.4	22.8	.30	0	3.0	45	980	<2.0
7/25	7.4	24.4	.44	0	1.5	14	680	<2.0
8/1	7.4	24.4	.74	0	10	53	380	<2.0
8/8	7.4	24.4	1.1	0	3.0	24	770	<2.0
8/15	7.2	24.4	.76	0	--	12	1100	<2.0
8/22	7.2	24.4	.91	0	--	4.5	590	<2.0
8/29	7.5	23.3	.47	0	1.0	1.5	310	<2.0
9/5	7.4	23.3	.30	0	2.0	3.0	340	<2.0
9/12	7.4	23.3	.40	0	3.0	5.0	140	<2.0
9/19	7.6	22.8	.28	0	4.0	8.5	26	<2.0
9/26	7.4	21.7	.32	0	7.5	9.0	49	<2.0
10/3	7.4	20.0	.34	0	--	9.5	48	<2.0
10/10	7.3	18.3	.34	0	5.5	8.5	40	<2.0
10/17	7.4	17.8	.36	0	<1.0	2.0	86	<2.0
10/24	7.4	16.1	.35	0	1.5	15	75	<2.0
10/31	7.5	16.7	.47	0	12	14	330	<2.0
11/7	7.4	16.1	.60	0	1.0	4.5	460	<2.0
11/14	7.6	15.0	.44	0	<1.0	14	110	<2.0
11/28	7.7	13.9	.46	0	5.0	14	1000	<2.0
12/5	7.4	12.2	.51	0	<1.0	11	620	<2.0
12/12	7.4	9.4	.63	.10	1.0	1.5	1300	<2.0
12/19	7.3	8.3	.50	.30	1.0	1.0	53	<2.0
1/2/78	7.2	7.8	1.0	.20	<1.0	1.0	6000	<2.0
1/9	7.3	5.6	.86	.30	<1.0	<1.0	120	<2.0
1/23	7.2	3.9	.64	.05	<1.0	<1.0	4.0	<2.0
1/30	7.2	4.4	.75	.30	1.0	1.0	440	<2.0
2/13	8.2	3.9	1.0	.30	<1.0	1.0	35	<2.0
2/20	7.2	3.9	.76	.20	<1.0	<1.0	280	<2.0
2/27	7.1	3.9	.75	.15	<1.0	1.0	1.0	<2.0
3/6	7.2	4.4	.85	.20	<1.0	1.0	28	<2.0
3/13	7.0	4.4	.82	.15	<1.0	1.5	320	<2.0
3/20	7.2	6.7	.92	0	1.0	1.0	410	<2.0
3/27	7.2	7.2	.78	.10	<1.0	<1.0	570	<2.0
4/3	7.2	7.8	1.1	0	<1.0	1.0	2000	<2.0
4/10	7.4	10.0	.99	.10	--	--	--	<2.0
4/17	7.2	11.1	1.0	.30	9.0	16	20	<2.0
4/24	CLOSED							
5/1	7.2	14.4	.68	0	--	26	--	<2.0
5/8	7.2	13.3	.48	0	--	16	4500	<2.0
5/22	7.2	14.4	.50	0	--	16	2600	<2.0
5/29	7.2	16.7	.39	0	--	78	1700	<2.0
mean			.63	.07		11	750	
std. dev.			.25	.11		16	1239	

TABLE D-7. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 28 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.6	23.3	.33	.45	1.0	2.5	2.5	<2.0
7/25	7.5	24.4	.41	.30	<1.0	1.0	3.5	<2.0
8/1	7.5	21.7	.80	.45	3.5	9.5	15	<2.0
8/8	7.4	25.6	.87	.45	<1.0	<1.0	3.0	<2.0
8/15	7.3	24.4	1.3	.30	—	7.5	9.0	<2.0
8/22	7.4	24.4	.35	.20	--	<1.0	1.0	<2.0
8/29	7.7	23.3	.30	.45	1.0	2.5	<1.0	<2.0
9/5	7.4	23.9	.26	.30	<1.0	1.0	<1.0	<2.0
9/12	7.3	23.3	.26	.30	<1.0	<1.0	1.0	<2.0
9/19	7.7	23.3	.26	.30	<1.0	<1.0	4.0	<2.0
9/26	7.3	23.3	.30	.55	2.5	2.5	4.5	<2.0
10/3	7.6	21.1	.41	.45	--	2.5	1.0	<2.0
10/10	7.5	20.0	.30	.30	<1.0	1.0	1.0	<2.0
10/17	7.6	18.9	.94	.55	1.5	5.0	53	<2.0
10/24	7.6	17.8	.51	.30	<1.0	3.0	1.0	<2.0
10/31	7.6	18.9	.46	.30	<1.0	120	1.0	<2.0
11/7	7.4	17.8	.63	.45	52	61	120	<2.0
11/14	CLOSED							
11/28	7.7	12.8	.35	.45	<1.0	29	4.0	<2.0
12/5	7.6	12.2	.45	.30	1.0	14	1.5	<2.0
12/12	7.2	8.9	.30	.45	--	1.0	1.0	<2.0
12/19	7.6	9.4	.68	.45	1.0	6.0	1.0	<2.0
1/2/78	7.4	8.9	.45	.80	1.0	3.0	20	<2.0
1/9	7.4	5.6	.41	.55	1.0	9.5	11	<2.0
1/23	7.2	3.9	.50	.45	<1.0	1.0	2.0	<2.0
1/30	7.3	4.4	.49	.55	<1.0	2.0	1.0	<2.0
2/13	7.5	3.3	.98	.45	<1.0	2.0	1.0	<2.0
2/20	7.2	3.3	.46	.55	1.0	1.0	1.0	<2.0
2/27	7.3	3.9	.55	.30	<1.0	1.0	<1.0	<2.0
3/6	7.1	4.4	.55	.45	<1.0	<1.0	1.0	<2.0
3/13	7.3	5.6	.68	.55	<1.0	1.0	1.0	<2.0
3/20	7.4	5.6	1.0	.20	1.0	1.0	4.0	<2.0
3/27	7.4	6.7	.82	.20	1.0	1.0	<1.0	<2.0
4/3	7.2	8.9	.82	.55	<1.0	<1.0	1.0	<2.0
4/10	7.2	10.0	.96	.30	--	--	--	<2.0
4/17	7.3	12.2	.82	.30	<1.0	3.5	52	<2.0
4/24	7.2	12.2	.38	.15	--	1.0	1.5	<2.0
5/1	CLOSED							
5/8	7.4	12.2	.43	.45	--	100	66	<2.0
5/22	7.4	15.0	.37	.55	--	74	58	<2.0
5/29	--	16.7	.28	.45	--	650	--	<2.0
mean			.55	.41		29	12	
std. dev.			.26	.13		107	25	

TABLE D-8. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 29 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.4	21.7	.44	.30	84	88	80	<2.0
7/25	7.4	21.1	.51	.30	30	32	30	<2.0
8/1	7.4	21.1	1.2	.30	4.5	6.0	19	<2.0
8/8	7.3	21.1	1.1	.45	72	81	76	<2.0
8/15	7.4	21.1	1.3	.30	--	20	16	<2.0
8/22	7.2	23.3	.34	.05	--	3.5	6.0	<2.0
8/29	7.6	22.2	.41	.30	35	40	35	<2.0
9/5	7.4	22.2	.46	.80	39	100	98	<2.0
9/12	7.4	22.8	.35	0	14	17	29	<2.0
9/19	7.6	23.3	.28	.20	8.0	18	8.0	<2.0
9/26	7.4	21.1	.37	.20	11	12	18	<2.0
10/3	7.6	20.0	.44	.20	--	25	28	<2.0
10/10	7.4	19.4	.36	.45	15	29	20	<2.0
10/17	7.4	17.8	.44	.30	3.0	6.0	9.5	<2.0
10/24	7.4	17.8	.47	.45	40	57	58	<2.0
10/31	7.6	20.0	.55	.20	120	130	130	<2.0
11/7	7.4	16.7	.72	.80	34	29	35	<2.0
11/14	7.4	16.7	.56	.45	7.0	9.5	26	<2.0
11/28	7.7	14.4	.71	.45	28	41	44	<2.0
12/5	7.2	12.2	.56	.55	29	33	44	<2.0
12/12	7.2	11.1	.36	.45	2.0	7.0	13	<2.0
12/19	7.2	10.0	.61	.80	4.5	9.5	12	<2.0
1/2/78	7.2	10.6	.55	.45	1.5	5.5	14	<2.0
1/9	7.3	7.2	.67	.60	1.0	3.5	6.0	<2.0
1/23	7.2	4.4	.52	.45	4.0	8.5	11	<2.0
1/30	7.2	4.4	.94	.55	19	25	19	<2.0
2/13	7.6	3.9	.76	.55	7.5	11	12	<2.0
2/20	7.0	3.3	.81	.55	6.0	9.0	8.0	<2.0
2/27	7.0	5.6	.72	.20	9.0	12	19	<2.0
3/6	7.0	5.6	.79	.30	8.0	9.5	23	<2.0
3/13	7.0	5.6	.50	.45	28	33	37	<2.0
3/20	7.0	6.7	.86	.45	11	12	15	<2.0
3/27	7.2	7.8	.69	.30	54	63	64	<2.0
4/3	7.2	7.8	.90	.45	16	19	6.0	<2.0
4/10	7.1	10.0	1.0	.30	--	--	--	<2.0
4/17	7.3	11.1	1.1	0	<1.0	7.0	1800	<2.0
4/24	7.1	13.9	.55	.20	--	27	67	<2.0
5/1	7.2	14.4	.47	.20	--	1.0	--	<2.0
5/8	7.2	12.2	.45	.45	--	17	39	<2.0
5/22	7.4	15.6	.38	.30	--	69	180	<2.0
5/29	7.4	15.6	.42	.30	--	110	160	<2.0
mean			.62	.37		31	85	
std. dev.			.26	.19		32	285	

TABLE D-9. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 30 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/78	7.3	21.7	.60	.05	<1.0	3.0	3.5	<2.0
7/25	7.4	21.7	.30	.05	<1.0	2.0	1.0	<2.0
8/1	7.4	22.2	1.1	.45	<1.0	1.5	1.0	<2.0
8/8	7.3	23.3	1.0	.10	1.0	1.0	1.0	<2.0
8/15	7.4	23.3	.75	.20	--	<1.0	1.0	<2.0
8/22	7.2	23.3	.41	.30	--	<1.0	1.0	<2.0
8/29	7.5	22.8	.38	.15	1.5	1.5	1.0	<2.0
9/5	7.4	22.2	.36	.30	<1.0	<1.0	<1.0	<2.0
9/12	7.6	22.2	.40	.10	1.5	2.0	3.0	<2.0
9/19	7.6	21.1	.28	.30	15	16	17	<2.0
9/26	7.4	20.0	.35	.20	1.5	2.5	<1.0	<2.0
10/3	7.6	18.9	.46	.30	--	19	4.0	<2.0
10/10	7.3	16.7	.43	.30	<1.0	1.0	<1.0	<2.0
10/17	7.4	15.0	.48	.55	<1.0	1.5	<1.0	<2.0
10/24	7.4	14.4	.40	.10	1.0	3.5	1.5	<2.0
10/31	7.3	19.4	.46	.30	1.0	3.5	1.0	<2.0
11/7	7.3	16.1	.50	.55	1.5	4.0	<1.0	<2.0
11/14	7.4	13.3	.56	.80	<1.0	5.0	1.0	<2.0
11/28	7.5	10.6	.60	.80	1.0	1.0	32	<2.0
12/5	7.2	10.0	.42	.80	<1.0	1.0	1.5	<2.0
12/12	7.3	7.8	.34	.55	1.0	1.0	1.0	<2.0
12/19	7.2	7.2	.59	.80	<1.0	<1.0	2.0	2.0
1/2/78	7.2	5.0	.58	.55	1.0	1.5	<1.0	<2.0
1/9	7.1	5.6	.75	.55	1.0	1.0	2.5	<2.0
1/23	7.0	2.8	.45	.55	<1.0	<1.0	2.5	<2.0
1/30	7.1	3.3	.69	.80	<1.0	1.0	<1.0	<2.0
2/13	7.0	2.2	.99	.30	1.0	1.0	<1.0	<2.0
2/20	7.0	2.2	.59	.80	<1.0	<1.0	<1.0	<2.0
2/27	7.2	3.3	.65	.80	<1.0	1.0	1.5	<2.0
3/6	7.0	3.3	.62	.55	<1.0	<1.0	4.0	<2.0
3/13	7.2	4.4	.56	.55	<1.0	<1.0	1.0	<2.0
3/20	7.0	6.1	.74	.30	<1.0	1.0	2.0	<2.0
3/27	7.0	6.7	.69	.55	34	45	40	<2.0
4/3	7.2	7.8	.92	.30	<1.0	4.5	1.0	<2.0
4/10	7.2	10.0	.91	.30	--	--	--	<2.0
4/17	7.2	12.2	.74	.45	1.0	3.5	4.0	<2.0
4/24	7.2	12.2	.46	.30	--	8.5	5.5	<2.0
5/1	7.4	12.2	.45	.20	--	33	--	<2.0
5/8	7.1	12.2	.40	.45	--	13	13	<2.0
5/22	7.2	16.1	.30	.45	--	73	100	<2.0
5/29	7.2	16.7	.35	.20	--	22	46	<2.0
mean			.56	.41		7.0	7.6	
std. dev.			.21	.23		14	19	

TABLE D-10. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 31 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/78	7.4	23.3	.40	0	1.0	11	1200	<2.0
7/25	7.4	21.1	.40	0	<1.0	9.0	530	<2.0
8/1	7.3	23.3	1.4	0	1.5	4.5	290	<2.0
8/8	7.4	24.4	1.0	0	1.0	8.0	150	<2.0
8/15	7.2	23.9	1.5	0	--	14	240	<2.0
8/22	7.4	23.3	.61	0	--	20	230	<2.0
8/29	7.4	23.3	.41	0	1.5	8.5	310	<2.0
9/5	7.4	23.3	.35	.20	2.0	12	130	<2.0
9/12	7.2	23.3	.38	0	1.5	28	290	<2.0
9/19	7.6	22.2	.45	0	1.5	32	350	<2.0
9/26	7.2	22.2	.51	.05	--	530	850	<2.0
10/3	7.3	20.6	.78	0	--	1300	1800	<2.0
10/10	7.4	18.9	.40	0	1.0	1.0	94	<2.0
10/17	7.6	17.2	.71	0	<1.0	12	2600	<2.0
10/24	7.4	16.1	.45	.10	1.0	19	840	<2.0
10/31	7.4	18.9	.56	0	12	41	370	<2.0
11/7	7.4	16.1	1.0	0	<1.0	14	550	<2.0
11/14	7.6	14.4	.58	0	5.5	110	--	<2.0
11/28	7.7	13.3	.71	0	<1.0	30	1700	<2.0
12/5	7.4	11.1	.44	.15	<1.0	3.5	660	<2.0
12/12	7.3	10.0	.59	.10	1.0	20	2000	<2.0
12/19	7.4	8.9	.73	.30	<1.0	1.0	150	<2.0
1/2/78	7.2	7.8	.86	0	1.5	17	1700	<2.0
1/9	CLOSED							
1/23	7.2	3.9	.78	.20	<1.0	1.5	46	<2.0
1/30	7.1	3.9	.85	.25	<1.0	1.0	99	<2.0
2/13	7.6	3.9	.95	.20	1.0	2.0	98	<2.0
2/20	7.2	3.9	.85	.30	<1.0	1.0	160	<2.0
2/27	7.0	3.3	.91	.20	1.5	2.5	150	<2.0
3/6	7.1	3.9	.85	.30	<1.0	<1.0	78	<2.0
3/13	7.2	6.7	.79	.30	<1.0	<1.0	17	<2.0
3/20	7.2	6.7	.85	.05	3.5	4.0	120	<2.0
3/27	7.2	7.2	.69	.20	<1.0	3.5	77	<2.0
4/3	7.6	8.3	.98	.20	<1.0	2.0	6.2	<2.0
4/10	7.4	11.1	1.1	.20	--	--	--	<2.0
4/17	7.3	11.1	1.3	0	6.5	27	3400	<2.0
4/24	7.2	12.2	.75	0	--	2.5	930	<2.0
5/1	7.2	11.7	1.1	0	--	32	1200	<2.0
5/8	7.2	12.2	.55	0	--	10	840	<2.0
5/22	7.4	17.8	.46	0	--	8.0	1700	<2.0
5/29	7.2	16.1	1.2	0	--	1300	--	<2.0
mean			.75	.08		93	701	
std. dev.			.29	.11		296	811	

TABLE D-11. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 34 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.3	26.1	.50	.30	16	23	40	2.0
7/25	7.3	27.8	.58	.10	7.0	24	53	<2.0
8/1	7.3	20.0	1.2	.80	<1.0	<1.0	<1.0	<2.0
8/8	7.3	25.6	.70	.05	<1.0	31	40	<2.0
8/15	7.4	26.7	.55	.30	--	4.0	7.0	<2.0
8/22	7.4	25.0	.45	.45	--	9.0	15	<2.0
8/29	7.4	26.7	.30	.05	<1.0	5.0	40	<2.0
9/5	7.6	24.4	.41	.70	<1.0	5.0	25	<2.0
9/12	7.4	25.0	.40	.15	1.0	1.5	6.0	<2.0
9/19	7.6	24.4	.30	.30	1.0	1.0	6.5	<2.0
9/26	7.2	22.2	.36	.45	11	23	47	<2.0
10/3	7.4	22.2	.40	.20	--	4.5	4.5	<2.0
10/10	7.3	20.0	.44	.20	<1.0	1.5	12	<2.0
10/17	7.4	18.9	.53	.45	<1.0	8.5	16	<2.0
10/24	7.4	18.9	.41	0	1.0	15	16	<2.0
10/31	7.3	18.9	.46	.15	7.5	270	99	<2.0
11/7	7.4	16.7	.61	.30	7.5	37	140	<2.0
11/14	7.4	13.3	.68	.30	10	46	310	<2.0
11/28	7.7	12.2	.69	.30	--	380	2300	<2.0
12/5	7.3	12.2	.50	.20	<1.0	6.0	6.5	<2.0
12/12	7.3	8.9	.48	.55	--	1.0	4.5	<2.0
12/19	7.2	8.9	.58	.55	11	32	54	<2.0
1/2/78	7.3	6.7	1.1	.20	11	20	37	<2.0
1/9	7.3	6.7	.91	.30	7.5	25	28	<2.0
1/23	7.2	3.9	2.4	.55	21	380	1300	<2.0
1/30	7.2	3.3	.79	.30	--	1100	1000	<2.0
2/13	7.0	3.9	1.2	.15	7.5	260	190	<2.0
2/20	7.0	3.9	.87	.30	2.0	2.5	1.0	<2.0
2/27	7.2	3.9	1.0	.55	2.0	12	7.0	<2.0
3/6	7.2	3.3	.71	.45	<1.0	1.5	2.5	<2.0
3/13	7.0	5.0	.60	.55	2.5	25	44	<2.0
3/20	7.2	5.6	.98	.30	5.5	61	76	<2.0
3/27	7.2	6.7	1.1	.55	10	140	160	<2.0
4/3	7.4	7.8	1.0	.20	1.0	25	39	<2.0
4/10	7.4	11.1	1.2	.05	--	--	--	<2.0
4/17	7.2	13.3	1.2	.30	<1.0	5.0	17	<2.0
4/24	7.0	13.3	.85	.20	--	100	1500	<2.0
5/1	7.2	13.3	.98	0	--	15	5500	<2.0
5/8	7.2	13.3	.57	.20	--	--	42	<2.0
5/22	7.2	14.4	.45	.05	--	15	120	<2.0
5/29	--	16.7	1.1	.15	--	60	460	<2.0
mean			.74	.29		107	344	
std. dev.			.39	.19		253	963	

TABLE D-12. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 35 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.2	20.6	.30	.15	1.0	2.0	5.5	<2.0
7/25	7.4	20.6	.42	.20	2.5	19	25	<2.0
8/1	7.4	20.6	1.0	.20	<1.0	12	<1.0	<2.0
8/8	7.2	21.1	.91	.05	1.0	10	1.0	<2.0
8/15	7.2	21.1	.60	.55	--	1.5	1.0	<2.0
8/22	7.2	20.6	.75	.55	--	1.0	<1.0	<2.0
8/29	7.4	20.6	.51	.10	<1.0	1.0	<1.0	<2.0
9/5	7.2	21.7	.49	.55	3.0	13	<1.0	<2.0
9/12	7.2	20.6	.36	.05	<1.0	1.0	<1.0	2.0
9/19	7.4	20.0	.36	.05	1.0	1.0	2.0	<2.0
9/26	7.4	20.0	.41	.80	1.0	<1.0	<1.0	<2.0
10/3	7.4	18.3	.55	.05	--	2.0	2.5	<2.0
10/10	7.3	16.7	.36	.10	<1.0	1.0	11	<2.0
10/17	7.4	17.8	.42	1.0	<1.0	<1.0	<1.0	<2.0
10/24	7.4	13.3	.53	.90	1.0	1.0	<1.0	<2.0
10/31	7.3	17.8	.58	.20	<1.0	17	38	<2.0
11/7	7.4	15.6	.43	.80	<1.0	<1.0	3.5	<2.0
11/14	7.4	13.3	.91	0	<1.0	5.5	56	<2.0
11/28	7.7	10.6	.46	1.0	<1.0	<1.0	1.0	<2.0
12/5	7.5	10.0	.75	.20	3.0	52	220	<2.0
12/12	7.2	7.8	.46	.30	<1.0	<1.0	2.5	<2.0
12/19	7.3	7.8	.60	.45	<1.0	1.5	2.0	<2.0
1/2/78	7.3	8.9	.68	.30	<1.0	14	29	<2.0
1/9	7.2	5.0	.62	.20	1.0	2.0	3.5	<2.0
1/23	7.1	3.9	.77	.30	<1.0	<1.0	<1.0	<2.0
1/30	7.2	3.3	.76	.45	<1.0	1.0	1.0	<2.0
2/13	7.0	3.3	.98	.20	<1.0	1.0	1.0	<2.0
2/20	7.0	3.3	.82	.30	<1.0	<1.0	3.5	<2.0
2/27	7.2	3.3	.98	.30	<1.0	4.0	1.0	<2.0
3/6	7.2	3.9	.80	0	<1.0	1.0	2.9	<2.0
3/13	7.0	3.9	.98	.20	<1.0	<1.0	4.5	<2.0
3/20	7.4	5.6	.74	.30	<1.0	1.0	3.0	<2.0
3/27	7.2	5.6	.95	.30	<1.0	1.0	8.0	<2.0
4/3	7.2	8.3	1.0	.15	<1.0	1.0	9.5	<2.0
4/10	7.3	10.0	.96	0	--	--	--	<2.0
4/17	7.2	12.2	.94	0	1.0	52	120	<2.0
4/24	7.0	12.2	.85	.10	--	1.0	350	<2.0
5/1	7.2	12.2	.62	0	--	470	--	<2.0
5/8	7.2	12.2	.62	.05	--	1.0	56	<2.0
5/22	7.2	14.4	.77	.10	--	12	370	<2.0
5/29	7.4	16.7	.62	0	--	45	170	<2.0
mean			.67	.28		19	39	
std. dev.			.22	.28		74	89	

TABLE D-13. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 36 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.5	20.0	.48	.80	<1.0	1.0	<1.0	<2.0
7/25	7.4	21.1	.58	.80	1.0	1.0	1.0	<2.0
8/1	7.5	20.0	.81	.80	3.5	3.5	4.5	<2.0
8/8	7.4	23.3	1.0	.80	<1.0	<1.0	1.0	<2.0
8/15	7.3	20.6	.75	.80	--	<1.0	2.5	<2.0
8/22	7.4	20.0	.40	.80	--	1.0	1.0	<2.0
8/29	7.4	19.4	.40	.90	1.0	1.0	1.0	<2.0
9/5	7.6	23.3	.36	.90	<1.0	1.0	<1.0	<2.0
9/12	7.4	23.3	.29	.90	13	13	5.0	<2.0
9/19	7.7	18.9	.29	.80	<1.0	<1.0	1.0	<2.0
9/26	7.2	19.4	.30	.10	<1.0	<1.0	1.0	<2.0
10/3	7.2	17.8	.51	.80	--	1.0	<1.0	<2.0
10/10	7.5	15.6	.32	.80	<1.0	<1.0	<1.0	<2.0
10/17	7.6	18.3	.31	.20	<1.0	<1.0	<1.0	<2.0
10/24	7.4	17.8	.47	0	<1.0	2.0	3.5	<2.0
10/31	7.4	14.4	.51	.80	1.0	1.0	5.0	<2.0
11/7	7.4	15.6	.80	.15	<1.0	3.0	5.0	<2.0
11/14	7.4	13.3	.61	.80	<1.0	1.0	9.0	<2.0
11/28	7.7	11.1	.56	0	1.0	4.5	36	<2.0
12/5	7.6	8.9	.50	.80	<1.0	1.0	1.0	<2.0
12/12	7.4	7.8	.38	1.0	<1.0	<1.0	1.0	<2.0
12/19	7.4	7.8	.55	.80	1.0	2.0	6.5	<2.0
1/2/78	7.3	4.4	.50	1.05	<1.0	<1.0	1.0	<2.0
1/9	7.4	3.3	.55	.90	<1.0	1.5	2.0	<2.0
1/23	7.9	3.3	.66	.80	<1.0	8.5	2.0	<2.0
1/30	7.2	2.8	.70	.80	2.0	11	12	<2.0
2/13	7.2	3.3	.75	.55	1.0	2.0	1.0	<2.0
2/20	7.2	3.3	.55	1.0	<1.0	2.0	1.0	<2.0
2/27	7.2	3.3	.64	.80	1.0	1.0	<1.0	<2.0
3/6	7.2	3.3	.71	.80	<1.0	<1.0	<1.0	<2.0
3/13	7.4	4.4	.96	.80	1.0	2.0	1.5	<2.0
3/20	7.2	5.6	.69	.80	1.0	1.0	1.0	<2.0
3/27	7.2	5.6	.81	.80	1.0	1.0	3.5	<2.0
4/3	7.2	7.2	1.0	.80	1.0	1.5	1.0	<2.0
4/10	7.4	8.9	.93	.80	--	--	--	<2.0
4/17	7.3	10.0	.76	.80	<1.0	1.0	1.5	<2.0
4/24	7.1	12.2	.45	.80	--	16	39	<2.0
5/1	7.4	14.4	.37	.70	--	9.0	11	<2.0
5/8	7.4	11.7	.44	.90	--	1.0	5.0	<2.0
5/22	7.4	16.7	.33	.80	--	1.0	5.5	<2.0
5/29	7.4	15.6	.34	.80	--	7.5	3.0	<2.0
mean			.57	.73		2.6	4.4	
std. dev.			.21	.26		3.8	8.2	

TABLE D-14. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 37 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.3	30.0	1.8	0	55	290	280	<2.0
7/25	7.4	26.7	2.5	0	880	1100	1100	<2.0
8/1	CLOSED							
8/8	7.4	29.4	7.1	0	380	780	1600	<2.0
8/15	7.4	26.7	5.1	0	--	4900	6600	<2.0
8/22	7.8	27.2	7.1	0	--	590	560	<2.0
8/29	7.5	30.0	7.6	0	--	440	550	<2.0
9/5	7.6	27.2	8.4	0	150	560	650	<2.0
9/12	7.4	26.1	.85	0	--	1100	970	<2.0
9/19	7.5	27.2	1.5	0	75	420	500	<2.0
9/26	7.2	26.7	2.3	0	--	130	360	<2.0
10/3	7.4	24.4	1.4	0	--	260	520	<2.0
10/10	7.3	20.0	1.1	0	1.0	12	300	<2.0
10/17	7.4	21.7	1.2	0	--	210	310	<2.0
10/24	7.4	20.0	1.1	0	20	340	1400	<2.0
10/31	7.3	26.0	1.3	0	--	840	2300	<2.0
11/7	7.2	18.9	1.3	0	--	260	1700	<2.0
11/14	7.4	14.4	0.65	.45	<1.0	7.5	19	<2.0
11/28	7.7	18.9	1.6	.10	76	550	9500	<2.0
12/5	7.6	18.3	0.91	0	75	300	4000	<2.0
12/12	7.3	17.8	2.1	0	21	310	8800	<2.0
12/19	7.4	11.7	1.3	0	5.5	100	1400	<2.0
1/2/78	7.3	5.6	.81	.20	1.0	5.5	8.5	<2.0
1/9	7.2	7.2	1.2	.20	2.0	3.0	680	<2.0
1/23	7.1	5.6	.65	0	10	36	49	<2.0
1/30	7.2	4.4	2.6	0	2.5	320	2000	<2.0
2/13	7.2	8.9	2.1	0	14	400	1700	<2.0
2/20	7.2	15.6	1.9	0	7.5	24	2700	<2.0
2/27	7.3	11.1	.74	0	8.5	520	1300	<2.0
3/6	7.0	8.9	.85	0	3.0	88	720	<2.0
3/13	7.0	12.2	1.3	0	50	400	1900	<2.0
3/20	7.2	15.6	3.0	0	22	1100	4000	<2.0
3/27	CLOSED							
4/3	7.3	14.4	3.1	0	31	460	1900	<2.0
4/10	7.2	12.2	1.4	0	--	--	--	<2.0
4/17	7.2	12.2	.96	.45	1.0	12	37	<2.0
4/24	7.0	15.6	2.3	0	--	300	3100	<2.0
5/1	CLOSED							
5/8	7.2	17.2	1.7	0	--	670	4100	<2.0
5/22	7.2	21.1	2.9	0	--	1300	7500	<2.0
5/29	CLOSED							
mean			2.3	.04		531	2086	
std. dev.			2.1	.11		825	2461	

TABLE D-15. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 38 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.4	16.7	--	.80	<1.0	<1.0	<1.0	<2.0
7/25	7.4	17.8	.45	.55	1.5	2.0	1.0	<2.0
8/1	7.4	18.3	.75	.45	<1.0	<1.0	<1.0	<2.0
8/8	7.3	19.4	.55	.45	<1.0	<1.0	<1.0	<2.0
8/15	7.4	18.9	.70	.55	--	1.0	<1.0	<2.0
8/22	7.2	17.8	.40	.80	--	<1.0	1.0	<2.0
8/29	7.5	18.3	.56	.80	<1.0	<1.0	<1.0	<2.0
9/5	7.6	19.4	.39	.80	<1.0	<1.0	1.0	<2.0
9/12	7.4	18.3	.48	.80	--	--	--	<2.0
9/19	7.7	17.8	.35	.80	<1.0	<1.0	1.0	<2.0
9/26	7.4	17.8	.43	.45	1.0	1.0	1.0	<2.0
10/3	7.2	17.8	.54	.80	--	1.0	1.5	<2.0
10/10	7.5	16.7	.36	.80	<1.0	<1.0	<1.0	<2.0
10/17	7.4	15.0	.35	.55	<1.0	1.0	1.0	<2.0
10/24	7.4	14.4	.45	.45	<1.0	1.0	1.0	<2.0
10/31	7.4	13.3	.65	.30	<1.0	2.0	1.0	<2.0
11/7	7.4	15.0	.93	.80	1.0	1.0	<1.0	<2.0
11/14	7.6	15.0	.81	.55	<1.0	1.0	8.5	<2.0
11/28	7.9	12.2	.95	.80	<1.0	<1.0	<1.0	<2.0
12/5	7.2	9.4	.43	.80	<1.0	1.0	<1.0	<2.0
12/12	7.3	10.0	.43	.55	<1.0	<1.0	2.0	<2.0
12/19	7.4	8.9	.65	.55	<1.0	25	2.5	<2.0
1/2/78	7.4	8.9	.62	.80	<1.0	<1.0	<1.0	<2.0
1/9	7.4	5.6	.91	.80	1.0	1.0	1.0	<2.0
1/23	7.2	5.6	.76	.80	1.0	3.0	1.0	<2.0
1/30	7.2	3.3	.88	.80	<1.0	<1.0	1.0	<2.0
2/13	7.2	3.9	.91	.80	1.5	4.0	2.0	<2.0
2/20	7.2	3.3	.81	.80	1.0	<1.0	1.0	<2.0
2/27	7.4	4.4	.62	.55	1.0	17	1.0	<2.0
3/6	7.2	5.6	.77	.80	<1.0	<1.0	7.5	<2.0
3/13	7.2	4.4	.82	.80	<1.0	1.0	1.0	<2.0
3/20	7.4	5.6	.59	.80	1.0	1.0	1.0	<2.0
3/27	7.2	5.6	.73	.80	1.0	2.5	1.5	<2.0
4/3	7.4	7.2	1.1	.55	<1.0	1.0	1.0	<2.0
4/10	7.4	10.0	.88	.55	--	--	--	<2.0
4/17	7.2	11.1	.84	.55	<1.0	<1.0	1.0	<2.0
4/24	7.2	8.9	.66	.80	--	5.0	7.5	<2.0
5/1	7.4	11.1	.46	.80	--	2.0	1.0	<2.0
5/8	7.4	12.2	.65	.45	--	1.0	1.0	<2.0
5/22	7.4	14.4	.35	.80	--	1.0	11	<2.0
5/29	7.6	15.1	.38	.80	--	3.0	1.5	<2.0
mean			.63	.68		2.0	1.7	
std. dev.			.21	.15		4.7	2.5	

TABLE D-16. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 42 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.2	21.1	.33	.80	1.0	12	1.0	<2.0
7/25	7.3	21.1	.51	.80	1.5	14	8.0	<2.0
8/1	CLOSED							
8/8	7.2	21.1	.80	.30	1.0	11	5.0	<2.0
8/15	7.2	23.3	.40	.55	--	8.5	4.5	<2.0
8/22	7.4	22.2	.35	.55	2.0	1.0	1.0	<2.0
8/29	7.2	22.2	.29	.30	1.0	2.0	<1.0	<2.0
9/5	7.4	21.7	.33	.45	2.0	4.5	--	<2.0
9/12	7.2	20.6	.32	.45	3.5	6.0	2.5	<2.0
9/19	7.3	22.2	.46	.55	--	20	27	<2.0
9/26	7.2	22.2	.29	.30	<1.0	3.5	3.0	<2.0
10/3	7.3	20.0	.50	.55	1.0	1.0	2.0	<2.0
10/10	7.5	20.0	.31	.55	<1.0	<1.0	1.0	<2.0
10/17	7.2	15.0	.73	.45	<1.0	1.0	1.0	<2.0
10/24	7.4	15.6	.58	.55	1.0	19	5.0	<2.0
10/31	7.4	17.8	.54	.30	<1.0	2.0	33	<2.0
11/7	7.2	15.6	.63	.55	2.5	8.0	33	<2.0
11/14	7.4	13.3	.48	.45	3.0	7.0	24	<2.0
11/28	7.2	11.1	.60	.55	1.5	1.5	26	<2.0
12/5	7.4	9.4	.75	.80	<1.0	<1.0	2.0	<2.0
12/12	7.3	8.3	.61	.55	<1.0	1.0	1.5	<2.0
12/19	7.6	8.3	.66	.55	1.0	1.5	2.0	<2.0
1/2/78	8.1	5.6	.96	.55	1.0	2.0	5.0	<2.0
1/9	7.4	3.3	.74	.55	<1.0	<1.0	3.0	<2.0
1/23	7.5	3.3	.82	.55	9.0	42	440	<2.0
1/30	7.4	3.3	1.0	.80	5.5	6.0	5.0	<2.0
2/13	7.4	3.3	1.2	.55	1.0	3.5	6.0	<2.0
2/20	7.2	3.3	.96	.30	<1.0	<1.0	1.0	<2.0
2/27	7.6	3.9	.94	.55	2.0	2.5	4.0	<2.0
3/6	7.4	3.3	.76	.55	<1.0	1.0	1.0	<2.0
3/13	7.2	5.6	.87	.55	<1.0	1.0	2.5	<2.0
3/20	7.8	6.7	.97	.55	<1.0	3.5	<1.0	<2.0
3/27	7.4	6.7	1.0	.50	1.0	2.0	10	<2.0
4/3	7.2	7.8	1.0	.55	<1.0	<1.0	2.5	<2.0
4/10	7.3	10.0	.94	.20	<1.0	<1.0	7.0	<2.0
4/17	7.4	12.2	.53	.30	22	28	91	<2.0
4/24	7.3	12.2	.60	.55	--	2.0	13	<2.0
5/1	CLOSED							
5/8	7.4	12.2	.43	.80	--	6.0	77	<2.0
5/22	7.4	16.7	.35	.30	--	6.0	99	<2.0
5/29	7.2	16.7	.49	.30	--	5.5	41	<2.0
mean			.64	.51		6.2	26	
std. dev.			.25	.16		8.5	73	

TABLE D-17. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 43 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.2	21.1	.33	.80	1.0	12	1.0	<2.0
7/25	7.2	21.1	.60	.80	28	31	37	6.0
8/1	7.2	24.4	.96	.55	32	28	92	<2.0
8/8	7.3	25.6	.60	.15	17	61	390	<2.0
8/15	7.2	23.2	.61	.20	--	1.5	47	<2.0
8/22	7.2	23.9	.45	.20	1.0	5.5	29	<2.0
8/29	7.4	23.3	.46	.20	5.0	7.0	6.5	<2.0
9/5	7.2	23.9	.29	.20	14	17	28	<2.0
9/12	7.2	24.4	.25	.20	4.0	5.5	5.0	<2.0
9/19	7.3	22.2	.45	.45	--	10	<1.0	<2.0
9/26	7.2	22.2	.30	.30	9.0	16	13	<2.0
10/3	7.3	21.1	.38	.20	4.0	4.0	3.5	<2.0
10/10	7.2	20.0	.32	.45	7.5	9.0	12	<2.0
10/17	7.4	17.8	.95	.30	1.0	1.0	<1.0	<2.0
10/24	7.2	15.6	.36	.45	2.5	2.5	2.0	<2.0
10/31	7.4	16.1	.33	.20	5.0	5.0	5.0	<2.0
11/7	7.4	16.1	.36	.45	1.0	1.0	7.5	<2.0
11/14	7.4	14.4	.45	.55	26	33	41	<2.0
11/28	7.2	13.3	.56	.45	21	21	71	<2.0
12/5	7.4	10.0	.50	.55	<1.0	<1.0	1.0	<2.0
12/12	7.3	8.9	.40	.45	3.0	4.0	5.0	<2.0
12/19	7.4	8.9	1.20	.55	1.5	23	5.0	<2.0
1/2/78	7.8	7.8	.54	.55	1.5	1.5	3.5	<2.0
1/9	7.3	5.6	1.0	.55	6.0	9.0	13	<2.0
1/23	7.4	3.3	.53	.55	1.0	2.0	4.5	<2.0
1/30	7.4	3.9	1.3	.55	13	14	100	<2.0
2/13	7.2	4.4	1.6	.55	5.0	8.5	7.5	<2.0
2/20	7.2	3.9	.79	.45	<1.0	<1.0	3.0	<2.0
2/27	7.2	5.6	1.0	.55	2.5	4.5	4.0	<2.0
3/6	7.4	3.9	.64	.55	<1.0	1.0	1.0	<2.0
3/13	7.3	6.6	.56	.80	2.5	5.5	2.0	<2.0
3/20	7.2	6.7	.87	.55	1.5	1.5	3.0	<2.0
3/27	7.4	6.1	.61	.40	1.5	2.0	6.0	<2.0
4/3	7.3	8.3	.95	.45	<1.0	1.0	1.0	<2.0
4/10	7.4	11.1	1.0	.45	2.0	2.0	<1.0	<2.0
4/17	7.3	13.9	.68	.55	1.0	2.0	1.5	<2.0
4/24	7.4	14.4	.43	.55	--	1.0	14	<2.0
5/1	7.2	14.4	.75	.55	--	1.0	28	<2.0
5/8	7.4	12.2	.39	.55	--	<1.0	17	<2.0
5/22	7.4	16.1	.29	.45	--	1.5	89	<2.0
5/29	7.2	18.3	.36	.30	--	2.5	11	<2.0
mean			.62	.45		8.7	27	
std. dev.			.31	.17		12	64	

TABLE D-18. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 44 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.2	21.7	.50	0	3.0	67	210	<2.0
7/25	7.4	21.1	1.5	0	5.5	16	380	<2.0
8/1	7.3	23.3	1.2	0	3.5	54	670	<2.0
8/8	7.5	23.3	.60	0	7.0	63	650	<2.0
8/15	7.4	25.0	1.0	0	--	61	580	<2.0
8/22	7.4	22.8	.55	0	7.0	26	200	<2.0
8/29	7.4	22.2	.52	0	1.0	9.0	430	<2.0
9/5	7.4	22.2	.33	0	3.5	20	1000	<2.0
9/12	7.4	21.1	.34	0	2.5	13	740	<2.0
9/19	7.3	21.1	1.2	0	--	3.5	320	<2.0
9/26	7.3	23.3	.70	0	1.0	11	38	<2.0
10/3	7.3	20.0	.54	0	2.5	3.0	160	<2.0
10/10	7.4	20.0	.93	.10	1.0	10	190	<2.0
10/17	7.4	16.7	1.2	0	11	23	190	<2.0
10/24	7.5	15.6	.93	0	4.5	50	260	<2.0
10/31	7.6	15.6	.65	0	3.5	56	670	<2.0
11/7	7.3	16.1	.82	0	4.0	62	1100	<2.0
11/14	7.4	15.0	.81	0	2.0	27	950	<2.0
11/28	7.4	12.8	.56	0	4.5	64	1000	<2.0
12/5	7.8	10.6	.46	.05	1.0	56	320	<2.0
12/12	7.1	10.0	.55	0	3.0	30	390	<2.0
12/19	7.6	9.4	.90	0	1.0	30	180	<2.0
1/2/78	7.9	8.3	1.0	0	2.0	42	1100	<2.0
1/9	7.5	5.6	2.0	0	1.0	19	830	<2.0
1/23	7.4	4.4	1.0	.05	21	84	940	<2.0
1/30	7.2	4.4	1.6	0	11	86	1000	<2.0
2/13	7.4	3.9	1.4	0	6.0	59	270	<2.0
2/20	7.2	3.9	1.1	0	6.5	72	460	<2.0
2/27	7.2	4.4	1.0	0	4.0	57	790	<2.0
3/6	7.4	5.6	.98	0	2.0	35	620	<2.0
3/13	7.4	5.6	.78	0	1.0	40	400	<2.0
3/20	7.8	6.7	1.3	0	<1.0	39	580	<2.0
3/27	7.4	6.1	.90	0	16	270	660	<2.0
4/3	7.4	7.8	1.1	0	8.5	38	970	<2.0
4/10	7.5	11.1	1.2	0	1.5	23	1200	<2.0
4/17	7.4	12.2	1.3	0	6.0	61	2300	<2.0
4/24	7.7	14.4	.80	0	--	93	2200	<2.0
5/1	7.4	12.2	.83	0	--	22	1700	<2.0
5/8	7.6	14.4	.46	0	--	22	2000	<2.0
5/22	7.4	16.7	.37	0	--	--	1400	<2.0
5/29	7.2	17.8	.80	0	--	84	2400	<2.0
mean			.90	.005		48	791	
std. dev.			.37	.02		44	607	

TABLE D-19. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 45 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.2	22.2	.31	.80	1.0	5.0	<1.0	<2.0
7/25	7.2	24.4	.47	1.2	<1.0	1.0	<1.0	<2.0
8/1	7.4	22.2	.53	.80	26	28	25	<2.0
8/8	7.1	23.9	.60	.90	4.0	5.0	<1.0	<2.0
8/15	6.8	23.3	.50	.80	--	--	3.0	<2.0
8/22	7.0	23.3	.42	.80	<1.0	1.0	2.0	<2.0
8/29	6.9	23.3	.40	1.0	<1.0	1.0	<1.0	<2.0
9/5	7.1	23.3	.31	1.0	--	<1.0	<1.0	<2.0
9/12	7.0	22.2	.30	1.2	<1.0	<1.0	<1.0	<2.0
9/19	7.0	23.3	.41	1.0	--	<1.0	<1.0	<2.0
9/26	7.0	20.6	.30	1.0	<1.0	<1.0	<1.0	<2.0
10/3	7.2	18.9	.42	1.0	<1.0	<1.0	<1.0	<2.0
10/10	7.2	18.3	.35	1.0	<1.0	<1.0	<1.0	<2.0
10/17	7.2	15.6	.60	1.0	<1.0	<1.0	1.0	<2.0
10/24	7.6	15.6	.47	1.0	1.0	1.5	1.0	<2.0
10/31	7.0	16.7	.33	1.2	<1.0	1.0	1.0	<2.0
11/7	7.2	15.0	.38	1.0	<1.0	1.0	<1.0	<2.0
11/14	7.2	15.0	.42	.90	<1.0	1.0	1.5	<2.0
11/28	7.2	9.4	.56	1.0	<1.0	1.0	7.0	<2.0
12/5	7.3	9.4	.63	.55	<1.0	1.0	1.0	<2.0
12/12	7.2	8.9	.65	1.2	3.5	5.5	15	<2.0
12/19	7.3	7.8	.42	1.0	9.5	14	13	2.0
1/2/78	7.6	5.6	.58	1.05	<1.0	<1.0	<1.0	<2.0
1/9	7.2	6.1	.59	1.2	<1.0	<1.0	<1.0	<2.0
1/23	7.2	3.3	.97	.90	1.0	1.5	1.0	<2.0
1/30	7.0	3.3	1.0	1.0	<1.0	<1.0	<1.0	<2.0
2/13	6.8	3.3	1.2	1.2	<1.0	1.0	1.0	<2.0
2/20	7.2	3.3	.93	.80	<1.0	<1.0	<1.0	<2.0
2/27	7.8	3.9	1.0	.80	1.0	1.0	1.0	<2.0
3/6	7.2	3.3	.82	.80	<1.0	1.0	1.0	<2.0
3/13	7.0	4.4	.49	.55	1.5	3.5	62	<2.0
3/20	7.2	6.7	.91	.80	1.0	1.5	<1.0	<2.0
3/27	6.8	6.7	.76	.60	<1.0	<1.0	1.0	<2.0
4/3	7.2	7.8	1.1	.80	2.5	3.0	1.0	<2.0
4/10	6.9	11.1	.84	1.2	<1.0	1.0	1.5	<2.0
4/17	7.1	12.2	.69	.80	5.5	--	1.0	<2.0
4/24	6.8	12.2	.57	1.0	--	1.0	2.0	<2.0
5/1	7.0	13.3	.31	.80	--	27	67	<2.0
5/8	6.8	12.2	.45	1.0	--	<1.0	--	<2.0
5/22	7.2	15.0	.28	.55	--	2.5	3.0	<2.0
5/29	6.8	16.7	1.2	.80	--	3.5	16	<2.0
mean			.60	.93		2.9	5.7	
std. dev.			.26	.18		6.3	14.7	

TABLE D-20. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 46 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/78	7.4	20.0	.45	.80	4.5	5.5	43	<2.0
7/25	7.3	20.6	.71	.80	<1.0	1.0	98	<2.0
8/1	7.3	20.6	1.0	.55	1.5	7.0	7.5	<2.0
8/8	7.1	23.3	.80	.90	11	16	50	<2.0
8/15	7.0	23.3	.55	.80	--	--	<1.0	<2.0
8/22	7.2	23.3	.65	.80	1.0	1.0	9.0	<2.0
8/29	7.2	22.2	.42	1.0	1.0	17	15	<2.0
9/5	7.2	21.1	.38	.80	1.0	7.0	48	<2.0
9/12	7.2	22.8	.27	.90	6.0	9.0	9.0	<2.0
9/19	7.2	21.1	.40	1.0	--	20	39	<2.0
9/26	7.1	21.7	.34	1.0	1.0	2.0	3.0	<2.0
10/3	7.2	20.0	.39	1.0	1.5	2.0	3.0	<2.0
10/10	7.2	18.9	.35	1.0	3.0	2.5	3.5	<2.0
10/17	7.2	15.6	.68	1.0	<1.0	1.0	<1.0	<2.0
10/24	7.4	15.6	.45	1.0	19	32	30	<2.0
10/31	7.3	15.6	.70	.45	3.5	9.5	23	<2.0
11/7	7.3	15.6	.65	.55	<1.0	2.5	21	<2.0
11/14	7.3	13.3	.79	.80	1.5	3.0	12	<2.0
11/28	7.3	12.2	.49	1.2	1.5	3.0	34	<2.0
12/5	7.5	10.6	.61	.25	1.5	6.0	58	<2.0
12/12	7.2	8.9	.39	.80	<1.0	<1.0	2.0	<2.0
12/19	7.4	7.2	.55	.55	2.0	12	9.0	<2.0
1/2/78	7.7	7.8	.67	1.05	<1.0	1.0	1.5	<2.0
1/9	7.1	5.6	.76	.90	<1.0	<1.0	2.5	<2.0
1/23	7.1	3.3	1.3	1.0	1.0	1.0	1.0	<2.0
1/30	7.2	3.3	.74	.80	1.0	2.0	9.5	<2.0
2/13	7.2	3.9	1.1	.55	<1.0	1.0	62	<2.0
2/20	7.1	3.3	1.1	.80	<1.0	1.0	81	<2.0
2/27	7.3	3.9	.96	.80	<1.0	1.5	79	<2.0
3/6	7.2	3.9	.88	.80	1.0	1.5	130	<2.0
3/13	7.3	5.6	.59	.80	<1.0	<1.0	1.0	<2.0
3/20	7.2	5.6	1.0	.55	<1.0	1.0	89	<2.0
3/27	7.4	5.6	.74	.90	1.0	16	210	<2.0
4/3	7.3	7.8	1.0	.80	<1.0	16	79	<2.0
4/10	7.1	10.0	.76	.45	1.0	25	150	<2.0
4/17	7.1	11.1	.64	.45	1.0	13	130	<2.0
4/24	7.5	11.1	1.1	.80	--	1.5	10	<2.0
5/1	7.2	13.3	.45	.60	--	4.0	12	<2.0
5/8	7.2	13.3	.40	.55	--	25	31	<2.0
5/22	7.2	15.6	.27	.80	--	5.5	14	<2.0
5/29	7.0	17.8	.37	1.0	--	1.5	<1.0	<2.0
mean			.65	.79		6.9	39	
std. dev.			.26	.21		8.1	49	

TABLE D-21. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 48 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.4	25.6	.58	0	880	1700	2400	<2.0
7/25	7.3	25.6	.65	0	3.5	160	1500	<2.0
8/1	7.2	25.6	.70	0	8.5	500	1300	<2.0
8/8	7.2	25.0	1.1	0	<1.0	260	400	<2.0
8/15	7.2	26.7	.56	0	--	190	1200	<2.0
8/22	7.4	25.6	.80	0	<1.0	180	170	<2.0
8/29	7.2	25.6	.74	0	<1.0	20	120	<2.0
9/5	7.2	26.7	.50	0	110	610	830	<2.0
9/12	7.3	25.0	.56	0	39	130	970	<2.0
9/19	7.2	25.6	.51	0	--	64	110	<2.0
9/26	7.4	23.9	.39	0	<1.0	7.5	460	<2.0
10/3	7.4	23.3	.44	0	<1.0	<1.0	1100	<2.0
10/10	7.3	20.6	.54	0	1.0	10	670	<2.0
10/17	7.6	21.1	.55	0	<1.0	9.0	390	<2.0
10/24	7.4	18.9	.64	0	1.0	380	390	<2.0
10/31	7.4	20.0	.49	0	--	310	650	<2.0
11/7	7.4	20.0	.57	0	33	380	1400	<2.0
11/14	7.4	20.0	.78	0	--	590	920	<2.0
11/28	7.2	17.8	.61	0	1.0	330	2900	<2.0
12/5	7.5	15.6	.78	0	<1.0	370	1600	<2.0
12/12	7.2	14.4	.50	.05	<1.0	34	130	<2.0
12/19	7.4	13.3	.51	0	<1.0	55	1700	<2.0
1/2/78	7.7	14.4	.72	.55	3.5	1.0	170	<2.0
1/9	7.2	10.6	1.1	.30	1.0	7.0	51	<2.0
1/23	7.1	4.4	.83	.45	5.0	5.0	4.5	<2.0
1/30	7.4	8.9	.93	.05	<1.0	2.0	120	<2.0
2/13	7.4	8.9	1.0	0	1.0	16	530	<2.0
2/20	7.4	11.1	1.0	0	<1.0	46	740	<2.0
2/27	6.8	10.0	.79	0	2.5	88	980	<2.0
3/6	7.4	11.1	.92	0	1.5	180	1200	<2.0
3/13	7.2	11.1	.76	0	1.0	23	980	<2.0
3/20	7.2	11.1	.96	0	1.0	40	290	<2.0
3/27	7.4	11.1	.83	0	1.5	290	2900	<2.0
4/3	7.3	14.4	1.0	0	<1.0	28	1100	<2.0
4/10	7.3	14.4	1.1	0	1.0	50	770	<2.0
4/17	7.3	14.4	.67	0	<1.0	80	1000	<2.0
4/24	7.7	15.6	.69	0	--	220	1100	<2.0
5/1	7.4	18.9	.66	0	--	1200	5200	<2.0
5/8	7.4	16.7	.69	0	--	100	1500	<2.0
5/22	7.4	18.3	1.0	0	--	690	3500	<2.0
5/29	7.2	20.0	.52	0	--	470	1300	<2.0
mean			.72	.03		240	1091	
std. dev.			.20	.11		341	1042	

TABLE D-22. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 49 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.2	23.9	.32	1.0	12	16	25	<2.0
7/25	7.2	22.2	.65	1.0	7.5	11	12	<2.0
8/1	7.2	22.2	2.6	1.0	4.0	5.5	4.5	<2.0
8/8	7.0	23.3	.85	1.0	3.5	5.5	5.0	<2.0
8/15	7.0	23.9	1.0	1.0	--	14	12	<2.0
8/22	7.0	20.0	.51	1.0	3.5	5.5	12	<2.0
8/29	6.9	20.0	.52	1.2	1.5	3.0	1.0	<2.0
9/5	7.1	22.8	.29	1.0	2.5	4.5	5.5	<2.0
9/12	7.1	20.0	.25	1.0	4.5	7.5	13	<2.0
9/19	7.1	23.3	.36	1.2	--	9.0	11	<2.0
9/26	7.1	20.0	.29	1.2	9.0	11	13	<2.0
10/3	7.2	20.0	.35	1.2	2.0	2.0	3.0	<2.0
10/10	7.1	19.4	.29	1.2	16	21	30	<2.0
10/17	7.2	16.7	.80	1.2	<1.0	6.5	5.5	<2.0
10/24	7.4	16.7	.67	1.2	<1.0	<1.0	<1.0	<2.0
10/31	7.3	15.6	.36	.80	2.0	2.0	7.0	<2.0
11/7	7.4	15.6	.43	.55	19	26	27	<2.0
11/14	7.2	15.6	.40	1.05	9.0	34	18	<2.0
11/28	7.4	13.3	.71	1.2	5.0	5.0	8.5	<2.0
12/5	7.5	10.0	.51	1.0	1.0	1.0	4.5	<2.0
12/12	7.2	9.4	.37	1.0	<1.0	2.0	4.0	<2.0
12/19	7.4	8.9	.42	.55	<1.0	<1.0	4.0	<2.0
1/2/78	7.7	6.1	.64	1.05	1.0	2.5	3.5	<2.0
1/9	7.2	5.6	.60	.80	1.0	4.0	37	<2.0
1/23	7.2	3.3	.61	.90	6.5	8.0	6.0	<2.0
1/30	7.2	3.3	.82	.80	8.0	17	58	<2.0
2/13	7.2	3.9	1.1	.55	2.0	7.0	25	<2.0
2/20	7.2	3.3	.96	.80	1.0	1.5	3.5	<2.0
2/27	7.1	3.9	.69	.80	1.0	1.5	1.5	<2.0
3/6	7.3	3.9	.79	.80	1.0	2.5	21	<2.0
3/13	7.3	4.4	.51	.80	<1.0	1.0	3.0	<2.0
3/20	7.2	6.1	1.1	.80	1.0	2.0	4.5	<2.0
3/27	7.0	7.2	.71	.80	14	21	72	<2.0
4/3	7.2	8.9	1.0	.55	1.0	1.0	4.5	<2.0
4/10	7.1	12.2	.88	.80	1.5	1.5	5.0	<2.0
4/17	7.1	12.2	.44	.80	2.0	2.0	13	<2.0
4/24	7.5	12.2	.50	.80	--	7.0	18	<2.0
5/1	7.4	12.2	.34	1.05	--	3.0	15	<2.0
5/8	7.2	14.4	.46	.80	--	1.0	8.0	<2.0
5/22	7.0	16.7	.24	1.0	--	23	19	<2.0
5/29	7.0	17.8	.33	1.2	--	73	71	<2.0
mean			.63	.94		9.1	15	
std. dev.			.40	.20		13	17	

TABLE D-23. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 52 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.4	20.0	.40	.80	1.5	4.0	--	<2.0
7/25	7.2	24.4	.50	.80	<1.0	2.0	<1.0	<2.0
8/1	7.2	23.9	1.6	.30	<1.0	1.0	<1.0	<2.0
8/8	7.0	22.8	.80	.80	<1.0	<1.0	1.0	<2.0
8/15	7.0	23.3	.46	.55	--	<1.0	1.5	<2.0
8/22	7.1	20.6	.50	.80	120	130	120	<2.0
8/29	7.1	20.0	.36	.80	8.0	18	28	<2.0
9/5	7.1	23.3	.42	.80	1.0	3.5	5.5	<2.0
9/12	7.2	20.0	.25	.55	<1.0	1.0	<1.0	<2.0
9/19	7.2	21.1	.42	.90	--	<1.0	<1.0	<2.0
9/26	7.2	20.0	.34	.80	1.0	1.0	1.0	<2.0
10/3	7.3	20.0	.39	.80	1.0	2.5	<1.0	<2.0
10/10	7.1	20.0	.40	.80	<1.0	<1.0	<1.0	<2.0
10/17	7.2	16.7	.57	.80	<1.0	<1.0	<1.0	<2.0
10/24	7.4	15.6	.74	.55	<1.0	<1.0	2.5	<2.0
10/31	7.3	15.0	.43	.80	<1.0	<1.0	1.0	<2.0
11/7	7.4	14.4	.46	.30	<1.0	<1.0	2.5	<2.0
11/14	7.4	13.3	.60	.30	<1.0	<1.0	<1.0	<2.0
11/28	7.2	12.2	.52	1.0	7.0	7.0	3.0	<2.0
12/5	7.4	10.0	.69	.80	<1.0	<1.0	<1.0	<2.0
12/12	7.1	8.9	.36	1.0	1.0	1.0	1.0	<2.0
12/19	7.4	7.8	.75	.80	1.0	1.0	<1.0	<2.0
1/2/78	7.8	4.4	.65	1.05	12	17	11	<2.0
1/9	7.2	3.3	1.1	1.0	<1.0	1.0	1.0	<2.0
1/23	7.4	3.3	.58	.80	2.0	2.0	1.0	<2.0
1/30	7.2	3.3	.88	.30	<1.0	<1.0	2.0	<2.0
2/13	7.2	3.3	1.1	.55	4.0	17	21	<2.0
2/20	7.4	2.8	1.1	.55	<1.0	1.0	<1.0	<2.0
2/27	7.0	3.3	1.0	.80	1.0	1.0	1.0	<2.0
3/6	7.2	3.3	.80	.55	1.0	1.0	1.0	<2.0
3/13	7.2	3.3	.71	1.0	1.0	1.5	<1.0	<2.0
3/20	7.6	5.6	1.0	.80	1.0	1.0	<1.0	<2.0
3/27	7.4	5.6	.78	.80	<1.0	<1.0	13	33
4/3	7.2	7.2	.96	.80	<1.0	1.0	<1.0	<2.0
4/10	7.2	10.0	1.1	.55	1.0	1.0	1.0	<2.0
4/17	7.3	11.1	.54	.80	<1.0	<1.0	<1.0	<2.0
4/24	7.5	12.2	.58	.55	--	<1.0	1.0	<2.0
5/1	CLOSED							
5/8	7.1	12.2	.43	.80	--	1.0	<1.0	<2.0
5/22	7.2	14.4	.43	.80	--	<1.0	3.0	<2.0
5/29	7.2	15.6	.45	.80	--	3.0	<1.0	<2.0
mean			.65	.73		5.5	5.7	
std. dev.			.29	.20		20.7	19.7	

TABLE D-24. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 53 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.4	25.0	1.1	.10	35	71	280	<2.0
7/25	7.4	24.4	.50	0	5.0	8.0	110	<2.0
8/1	CLOSED							
8/8	7.2	24.4	2.5	0	26	180	1100	<2.0
8/15	7.0	24.4	.80	0	--	56	390	<2.0
8/22	7.4	24.4	.65	0	130	280	840	<2.0
8/29	7.2	24.4	.40	0	5.0	6.5	39	<2.0
9/5	7.4	23.3	.50	0	3.0	13	58	<2.0
9/12	7.4	22.8	.34	0	20	82	120	<2.0
9/19	7.3	23.3	.43	.05	--	170	360	<2.0
9/26	CLOSED							
10/3	7.2	20.0	.60	.10	--	13	32	<2.0
10/10	7.4	20.0	.46	0	10	86	150	<2.0
10/17	7.3	17.8	1.3	0	1.0	24	120	<2.0
10/24	7.2	17.8	.63	0	90	250	390	<2.0
10/31	7.4	17.8	.44	.20	--	270	420	<2.0
11/7	7.4	14.4	.46	.30	<1.0	<1.0	2.5	<2.0
11/14	7.4	13.9	.45	.20	1.0	3.0	34	<2.0
11/28	7.4	12.2	.56	.30	25	36	130	<2.0
12/5	7.4	11.1	.66	.15	1.0	6.5	35	<2.0
12/12	7.3	10.0	.40	.30	<1.0	31	36	<2.0
12/19	7.4	8.9	.56	.20	<1.0	12	11	<2.0
1/2/78	8.0	6.7	.61	.45	<1.0	1.0	1.0	<2.0
1/9	7.1	5.0	.61	.30	<1.0	24	31	<2.0
1/23	7.4	3.9	.50	.30	1.0	2.5	1.5	<2.0
1/30	7.2	4.4	1.4	.45	4.5	35	61	<2.0
2/13	7.2	4.4	1.0	.30	--	27	27	<2.0
2/20	7.3	3.9	1.0	.30	3.5	4.0	7.5	<2.0
2/27	7.6	3.3	1.0	.45	1.5	3.0	1.5	<2.0
3/6	7.4	4.4	.90	.55	<1.0	7.5	16	<2.0
3/13	7.4	6.6	.85	.30	2.0	4.0	1.0	<2.0
3/20	7.4	6.7	1.1	.30	4.0	9.5	16	<2.0
3/27	7.3	6.7	.64	.30	5.0	5.0	13	<2.0
4/3	7.3	7.8	1.0	.30	1.5	1.5	1.5	<2.0
4/10	7.2	11.1	1.1	.20	3.5	16	50	<2.0
4/17	7.4	12.2	.81	0	20	33	450	<2.0
4/24	CLOSED							
5/1	7.2	14.4	.48	.30	--	10	--	<2.0
5/8	7.4	14.4	.67	.10	--	--	150	<2.0
5/22	7.4	15.6	.60	.30	--	60	360	<2.0
5/29	7.2	17.8	.35	.05	--	31	42	<2.0
mean			.75	.19		50.6	159.1	
std. dev.			.40	.16		77.3	242.8	

TABLE D-25. BIOLOGICAL, CHEMICAL, AND PHYSICAL DATA, STATION 54 - BALTIMORE

Week of	pH	Temp. °C	Turbidity NTU	free Cl mg/l	Plate Count 48 hr. 35°C	Plate Count 96 hr. 35°C	Plate Count 9 day 20°C	coliform MPN/100 ml
7/18/77	7.4	18.3	.30	.80	5.0	270	8.0	<2.0
7/25	7.3	21.1	.45	.55	4.0	7.0	3.0	<2.0
6/1	CLOSED							
8/8	7.2	23.3	1.5	.55	1.0	1.0	1.0	<2.0
8/15	7.2	22.2	.60	.55	--	1.0	1.0	<2.0
8/22	7.4	20.6	.39	.55	5.0	7.5	1.0	<2.0
8/29	7.2	22.2	.41	.30	7.0	18	8.5	<2.0
9/5	7.5	20.0	.41	.80	10	10	3.0	<2.0
9/12	7.2	20.0	.29	.80	1.0	1.0	<1.0	<2.0
9/19	7.4	18.9	.36	.55	--	<1.0	<1.0	<2.0
9/26	7.2	20.0	.38	.55	<1.0	1.0	1.0	<2.0
10/3	7.4	18.3	.35	.55	<1.0	1.0	1.0	<2.0
10/10	7.4	18.9	.40	.45	<1.0	<1.0	<1.0	<2.0
10/17	7.3	15.0	.53	.80	<1.0	24	<1.0	<2.0
10/24	7.7	15.6	.43	.55	1.0	1.0	1.0	<2.0
10/31	7.4	16.7	.34	.55	5.5	11	7.5	<2.0
11/7	7.4	14.4	.45	.80	1.0	5.0	5.5	<2.0
11/14	7.4	12.8	.55	.80	1.0	10	1.0	<2.0
11/28	7.4	13.3	.70	.80	2.0	2.5	13	<2.0
12/5	7.8	12.2	.49	.55	3.0	29	16	<2.0
12/12	7.6	7.8	.50	.55	1.0	3.0	3.0	<2.0
12/19	7.6	7.8	.56	.80	4.5	10	12	<2.0
1/2/78	8.1	6.7	.61	.45	17	29	16	<2.0
1/9	7.4	3.9	.69	.55	1.0	4.5	3.5	<2.0
1/23	7.4	3.9	1.1	.55	2.5	8.0	3.5	<2.0
1/30	7.4	3.9	1.4	.80	140	160	150	<2.0
2/13	7.4	3.9	1.0	.80	2.0	4.5	1.5	<2.0
2/20	7.4	3.9	1.1	.55	3.5	6.0	4.5	<2.0
2/27	7.5	3.9	1.0	.80	2.5	3.5	3.5	<2.0
3/6	7.4	3.9	.65	.80	9.5	23	20	<2.0
3/13	7.4	5.6	1.0	.80	7.0	9.0	8.0	<2.0
3/20	7.4	5.6	.96	.80	2.5	4.0	2.5	<2.0
3/27	7.4	6.7	.83	.75	1.5	3.5	7.0	<2.0
4/3	7.5	8.3	1.0	.45	2.5	2.5	<1.0	<2.0
4/10	7.3	12.2	1.0	.55	36	40	39	<2.0
4/17	7.4	11.1	.75	.55	9.0	18	13	<2.0
4/25	7.4	12.2	.74	.80	--	15	4.0	<2.0
5/1	7.2	13.3	.41	.80	--	24	9.0	<2.0
5/8	7.4	12.2	.43	.55	--	20	85	<2.0
5/22	7.4	15.6	.27	.80	--	1.0	3.0	<2.0
5/29	7.4	16.1	.35	.55	--	4.0	4.5	<2.0
mean			.64	.65		20	12	
std. dev.			.31	.14		48	27	

APPENDIX E. MAJOR BIOCHEMICAL GROUPS

TABLE E-1. MAJOR BIOCHEMICAL GROUPS AT STATION 1, FREDERICK

35°C					20°C				
Biochemical Group	Number of Isolates	% of total number of isolates at Station 1	% of total isolates in group	Frequency of isolation, %	Biochemical Group	Number of isolates	% of total number of isolates at Station 1	% of total isolates in group	Frequency of isolation, %
8	26	5.8	4.3	34.6	9	19	4.2	2.0	38.5
9	17	3.8	4.1	30.8	8	85	18.9	11.5	57.7
26	3	0.7	1.4	11.5	3	77	17.1	35.5	61.5
3	57	12.7	29.7	38.5	26	5	1.1	2.7	11.5
24				0	24	10	2.2	5.5	7.7
17	3	0.7	1.9	11.5	17	1	0.2	0.6	3.8
10	62	13.8	40.0	34.6	22	11	2.4	6.6	15.4
18	4	0.9	4.1	15.4	18	16	3.6	13.3	15.4
22	7	1.6	7.2	7.7	5	8	1.8	13.3	26.9
5	2	0.4	2.4	7.7	11	54	12.0	93.1	30.8
13	48	10.7	71.6	30.8	6	12	2.7	26.7	26.7
16	43	9.6	66.2	30.8	14	14	3.1	31.8	11.5
28	23	5.1	35.9	7.7	10	17	3.8	44.7	23.1
6	5	1.1	7.9	11.5	27	3	0.7	8.6	7.7
14	12	2.7	23.1	19.2	2	27	6.0	79.4	30.8
11	21	4.7	43.8	26.9	28	23	5.1	69.7	11.5
27	35	7.8	76.1	15.4	1	15	3.3	48.4	34.6
1	17	3.8	45.9	23.1					
30	1	0.2	3.1	3.8					

TABLE E-2. MAJOR BIOCHEMICAL GROUPS AT STATION 4, FREDERICK

35°C					20°C				
Biochemical Group	Number of Isolates	% of total number of isolates at Station 4	% of total isolates in group	Frequency of isolation, %	Biochemical Group	Number of isolates	% of total number of isolates at Station 4	% of total isolates in group	Frequency of isolation, %
8	161	26.5	26.9	84.6	9	56	11.5	5.8	58.3
9	100	16.5	24.1	65.4	8	84	17.3	11.4	75.0
26	60	9.9	28.3	53.8	3	40	8.2	18.4	62.5
3	20	3.3	10.4	30.8	26	46	9.5	24.9	41.7
24	25	4.1	13.6	38.5	24	32	6.6	17.7	45.8
17	36	5.9	22.2	38.5	17	18	3.7	10.6	25.0
10				0	22	51	10.5	30.5	45.8
18	17	2.8	17.3	34.6	18	49	10.1	40.8	50.0
22	31	5.1	32.0	42.3	5	6	1.2	10.0	20.8
5	6	1.0	7.2	15.4	11	3	0.6	5.2	4.2
13	4	0.7	6.0	11.5	6	5	1.0	11.1	12.5
16				0	14	1	0.2	2.3	4.2
28				0	10				0
6	10	1.6	15.9	19.2	27	2	0.4	5.7	4.2
14	17	2.8	32.7	15.4	2	1	0.2	2.9	4.2
11	3	0.5	6.3	11.5	28				0
27	2	0.3	4.3	3.8	1	14	2.9	45.2	12.5
1	5	0.8	13.5	19.2					
30	5	0.8	15.6	15.4					

TABLE E-3. MAJOR BIOCHEMICAL GROUPS AT STATION 27, BALTIMORE

35°C					20°C				
Biochemical Group	Number of isolates	% of total number of isolates at Station 27	% of total isolates in group	Frequency of isolation, %	Biochemical Group	Number of isolates	% of total number of isolates at Station 27	% of total isolates in group	Frequency of isolation, %
8	34	14.8	5.7	47.6	9	121	31.1	12.6	70.8
9	12	5.2	2.9	23.8	8	121	31.1	16.4	62.5
26	6	2.6	2.8	14.3	3	13	3.3	6.0	37.5
3	4	1.7	2.1	14.3	26	7	1.8	3.9	16.7
24				0	24	11	2.8	6.1	8.3
17	3	1.3	1.9	9.5	17	17	4.4	10.0	25.0
10	48	21.0	31.0	38.1	22	2	0.5	1.2	8.3
18	3	1.3	3.1	9.5	18	2	0.5	1.7	8.3
22				0	5	31	8.0	51.7	33.3
5	41	17.9	49.4	14.3	11				0
13	12	5.2	17.9	19.0	6	6	1.5	13.3	20.8
16	1	0.4	1.5	4.8	14	2	0.5	4.5	4.2
28	3	1.3	4.7	9.5	10	18	4.6	47.4	12.5
6	5	2,2	7.9	14.3	27	15	3.9	42.9	16.7
14	11	4.8	21.2	14.3	2				0
11	12	5.2	25.0	19.0	28	1	0.3	3.0	4.2
27	2	0.9	4.3	9.5	1				0
1				0					
30	3	1.3	9.4	9.5					

TABLE E-4. MAJOR BIOCHEMICAL GROUPS AT STATION 34, BALTIMORE

35°C					20°C				
Biochemical Group	Number of isolates	% of total number of isolates at Station 34	% of total isolates in group	Frequency of isolation, %	Biochemical Group	Number of isolates	% of total number of isolates at Station 34	% of total isolates in group	Frequency of isolation, %
8	115	31.4	19.2	76.0	9	76	14.9	7.9	88.0
9	78	21.3	18.8	56.0	8	137	26.9	18.5	96.0
26	50	13.7	23.6	44.0	3	11	2.2	5.1	28.0
3	24	6.6	12.5	32.0	26	72	14.1	38.9	52.0
24	4	1.1	2.2	4.0	24	14	2.8	7.7	20.0
17	28	7.7	17.3	36.0	17	74	14.5	43.5	60.0
10				0	22	21	4.1	12.6	36.0
18	3	0.8	3.1	8.0	18	1	0.2	0.8	4.0
22	9	2.5	9.3	24.9	5	11	2.2	18.3	4.0
5	3	0.8	3.6	8.0	11				0
13	2	0.5	3.0	4.0	6	2	0.4	4.4	4.0
16	3	0.8	4.6	12.0	14	25	4.9	56.8	12.0
28				0	10				0
6	2	0.5	3.2	8.0	27				0
14	2	0.5	3.8	4.0	2				0
11				0	28				0
27				0	1				0
1				0					
30	1	0.3	3.1	4.0					

TABLE E-5. MAJOR BIOCHEMICAL GROUPS AT STATION 37, BALTIMORE

35°C					20°C				
Biochemical Group	Number of isolates	% of total number of isolates at Station 37	% of total isolates in group	Frequency of isolation, %	Biochemical Group	Number of isolates	% of total number of isolates at Station 37	% of total isolates in group	Frequency of isolation, %
8	73	19.9	12.2	78.3	9	232	56.7	24.1	81.8
9	54	14.7	13.0	60.9	8	64	15.6	8.6	77.3
26	37	10.1	17.5	43.5	3	41	10.0	18.9	59.1
3	58	15.8	30.2	69.6	26	15	3.7	8.1	31.8
24	19	5.2	10.3	26.1	24	4	1.0	2.2	9.1
17	16	4.4	9.9	39.1	17	9	2.2	5.3	31.8
10				0	22	17	4.2	10.2	22.7
18	10	2.7	10.2	26.1	18	2	0.5	1.7	9.1
22	23	6.3	23.7	34.8	5	1	0.2	1.7	4.5
5	6	1.6	7.2	13.0	11				0
13				0	6	2	0.5	4.4	9.1
16	3	0.8	4.6	13.0	14				0
28				0	10				0
6	6	1.6	9.5	13.0	27				0
14	5	1.4	9.6	13.0	2	2	0.5	5.9	9.1
11				0	28				0
27				0	1				0
1	12	3.3	32.4	4.3					
30	3	0.8	9.4	13.0					

TABLE E-6. MAJOR BIOCHEMICAL GROUPS AT STATION 43, BALTIMORE

35°C					20°C				
Biochemical Group	Number of isolates	% of total number of isolates at Station 43	% of total isolates in group	Frequency of isolation, %	Biochemical Group	Number of isolates	% of total number of isolates at Station 43	% of total isolates in group	Frequency of isolation, %
8	37	10.5	6.2	33.3	9	30	9.1	3.1	41.7
9	45	12.7	10.8	58.3	8	66	19.9	8.9	45.8
26	4	1.1	1.9	12.5	3	10	3.0	4.6	20.8
3	7	2.0	3.6	8.3	26	5	1.5	2.7	20.8
24	110	31.2	59.8	62.5	24	93	28.1	51.4	58.3
17	30	8.5	18.5	45.8	17	7	2.1	4.1	20.8
10				0	22	31	9.4	18.6	25.0
18	55	15.6	56.1	37.5	18	40	12.1	33.3	37.5
22	4	1.1	4.1	8.3	5				0
5				0	11				0
13				0	6	4	1.2	8.9	8.3
16	2	0.6	3.1	8.3	14				0
28				0	10				0
6	8	2.3	12.7	16.7	27	1	0.3	2.9	4.2
14	1	0.3	1.9	4.2	2				0
11	3	0.8	6.3	8.3	28				0
27				0	1				0
1	2	0.6	5.4	12.5					
30	6	1.7	18.8	12.5					

TABLE E-7. MAJOR BIOCHEMICAL GROUPS AT STATION 44, BALTIMORE

35°C					20°C				
Biochemical Group	Number of isolates	% of total number of isolates at Station 44	% of total isolates in group	Frequency of isolation, %	Biochemical Group	Number of isolates	% of total number of isolates at Station 44	% of total isolates in group	Frequency of isolation, %
8	75	19.4	12.5	88.0	9	185	38.1	19.2	100.0
9	24	6.2	5.8	44.0	8	116	23.9	15.7	80.0
26	29	7.5	13.7	40.0	3	15	3.1	6.9	24.0
3	12	3.1	6.3	28.0	26	18	3.7	9.7	32.0
24	22	5.7	12.0	16.0	24	14	2.9	7.7	16.0
17	25	6.5	15.4	28.0	17	17	3.5	10.0	28.0
10	45	11.7	29.0	36.0	22	22	4.5	13.2	32.0
18	4	1.0	4.1	12.0	18	10	2.1	8.3	36.0
22	20	5.2	20.6	28.0	5	2	0.4	3.3	8.0
5	22	5.7	26.5	24.0	11	1	0.2	1.7	4.0
13	1	0.3	1.5	4.0	6	10	2.1	22.0	28.0
16	6	1.6	9.2	8.0	14	2	0.4	4.5	8.0
28	38	9.8	59.4	20.0	10	3	0.6	7.8	8.0
6	12	3.1	19.0	24.0	27	14	2.9	4.0	12.0
14	3	0.8	5.8	12.0	2	3	0.6	8.8	4.0
11	9	2.3	18.8	16.0	28	9	1.9	27.3	8.0
27	7	1.8	15.2	16.0	1	2	0.4	6.5	4.0
1	1	0.3	2.7	4.0					
30	7	1.8	21.9	8.0					

TABLE E-8. MAJOR BIOLOGICAL GROUPS AT STATION 48, BALTIMORE

35°C					20°C				
Biochemical Group	Number of isolates	% of total number of isolates at Station 48	% of total isolates in group	Frequency of isolation, %	Biochemical Group	Number of isolates	% of total number of isolates at Station 48	% of total isolates in group	Frequency of isolation, %
8	77	27.4	12.9	66.7	9	244	59.7	25.3	91.7
9	85	30.2	20.5	70.8	8	67	16.4	9.1	54.2
26	23	8.2	10.8	16.7	3	10	2.4	4.6	29.2
3	10	3.6	5.2	12.5	26	17	4.2	9.2	20.8
24	4	1.4	2.2	4.2	24	3	0.7	1.7	4.2
17	21	7.5	13.0	16.7	17	27	6.6	15.9	33.3
10				0	22	12	2.9	7.2	25.0
18	2	0.7	2.0	4.2	18				0
22	3	1.1	3.1	8.3	5	1	0.2	1.7	4.2
5	3	1.1	3.6	4.2	11				0
13				0	6	4	1.0	8.9	12.5
16	7	2.5	10.8	12.5	14				0
28				0	10				0
6	15	5.3	23.8	12.5	27				0
14	1	0.4	1.9	4.2	2	1	0.2	8.8	4.2
11				0	28				0
27				0	1				0
1				0					
30	6	2.1	18.8	12.5					